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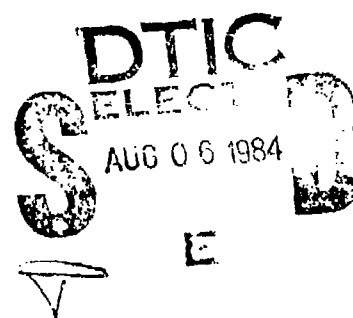
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# RAIN RATE CLIMATOLOGIES OVER MARINE REGIONS

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MAY 1984



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## CONTENTS

|   |    |
|---|----|
| 1. Introduction . . . . .                                   | 1  |
| 2. Rain Measurements . . . . .                              | 1  |
| 2.1 Over Land . . . . .                                     | 1  |
| 2.2 Over Ocean . . . . .                                    | 2  |
| 3. Converting Rain Amount to Rain Rate . . . . .            | 5  |
| 4. Application of the Method . . . . .                      | 6  |
| 5. Results . . . . .  | 7  |
| 6. Conclusions . . . . .                                    | 7  |
| References . . . . .  | 8  |
| Figures 1-14 . . . . .                                      | 9  |
| Appendix: Rain Rate Maps - All Oceans and Seasons . . . . . | 23 |
| Distribution . . . . .                                      | 80 |

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## 1. Introduction

Accurately assessing oceanic rain is still a major climatic problem. The difficulties arise not so much from physical or theoretical complexities but from a lack of data. Rain is not routinely measured at sea and must be indirectly estimated. Early precipitation maps prepared by direct extrapolation of coastal and island rain amounts frequently overestimated oceanic precipitation and are now considered unreliable. This report briefly describes a method of estimating the frequency of observation of two-minute average rain rates over the oceans. Maps of rain rate frequencies for different seasons and oceans are presented at the end of this report.

## 2. Rain Measurements

### 2.1 Over Land

Rain statistics have been collected at thousands of land sites for many years, but most of these data were oriented toward climatological or agricultural purposes. Thus, only daily or sometimes 6- or 3-hourly rain totals were recorded. Most rain gauges in general use today do not have the resolution necessary to measure short duration (few minutes) rain rates. A few special field measurement programs using a network of high speed rain gauges have been conducted, but the data available from these studies are quite meager (see Vanderhill, 1982, and the references cited therein). Consequently several empirical models have been developed to estimate the frequency distribution of

short-duration precipitation based on rain gauge observations over longer time intervals. Five models of this type are described by Tattleman and Grantham (1982) in a comprehensive survey of techniques for determining short duration rain rate statistics. Most of these models, however, are only useful for the land areas of the globe.

## 2.2 Over Ocean

Quantitative rain amounts are rarely measured aboard ships, but qualitative precipitation events are routinely recorded in the present weather reports of ships. Quantitative oceanic rain amounts may be inferred from these qualitative reports by employing an updated version of a technique first proposed by Tucker (1961). Tucker established a relationship between the present weather report numbers (WMO code) and the measured precipitation at British land stations. The present weather is normally observed every three hours and the results are coded using a scale running from 00 to 99. Only those weather conditions represented by codes 50 to 99 were considered by Tucker as contributing significant precipitation during the three hour observation period.

A partial list of the present weather codes and the assignment of an average hourly rain rate to the present weather code numbers are shown in Tables 1a and 1b. This hourly rain rate is one third of the three hour rain total originally assigned by Tucker.

Table 1a. Present weather WMO code (partial listing).

| <u>Code</u> | <u>Description</u>                         |
|-------------|--|
| 50          | Slight intermittent drizzle                |
| 51          | Slight continuous drizzle                  |
| 52          | Moderate intermittent drizzle              |
| 53          | Moderate continuous drizzle                |
| 54          | Thick intermittent drizzle                 |
| 55          | Thick continuous drizzle                   |
| 56          | Slight freezing drizzle                    |
| 57          | Moderate or thick freezing drizzle         |
| 58          | Slight drizzle and rain                    |
| 59          | Moderate or heavy drizzle and rain         |
| 60          | Slight intermittent rain                   |
| 61          | Slight continuous rain                     |
| 62          | Moderate intermittent rain                 |
| 63          | Moderate continuous rain                   |
| 64          | Heavy intermittent rain                    |
| 65          | Heavy continuous rain                      |
| 66          | Slight freezing rain                       |
| 67          | Moderate or heavy freezing rain            |
| 68          | Slight rain or drizzle and snow            |
| 69          | Moderate or heavy rain or drizzle and snow |
| 70          | Slight intermittent snow                   |
| .           | .  |
| .           | .  |
| 80          | Slight rain showers                        |
| .           | .  |
| .           | .  |
| 99          | Heavy thunderstorm with hail               |

Table 1b. Assignment of rain rates (mm/hr) to present weather codes.

|    | 0    | 1   | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    |
|----|------|-----|------|------|------|------|------|------|------|------|
| 5- | 0    | .31 | .31  | .62  | .62  | 1.24 | .31  | .94  | .31  | .94  |
| 6- | .31  | .62 | .94  | 1.88 | 1.36 | 2.71 | .62  | 2.30 | .62  | 2.30 |
| 7- | .31  | .62 | .94  | 1.88 | 1.36 | 2.71 | 0    | 0    | 0    | 0    |
| 8- | .31  | .94 | 1.36 | .31  | 1.15 | .31  | 1.15 | .31  | 2.30 | .31  |
| 9- | 2.30 | .62 | 2.30 | .62  | 2.30 | 1.25 | 1.25 | 2.71 | 0    | 2.71 |

Tucker's coefficients expressing the relationship between "present weather" codes and rain amounts were based on data from the United Kingdom only. Dorman and Bourke (1978) have found that an air temperature correction is necessary to accurately extend Tucker's method to tropical regions of the world. The correction is made using the linear regression equation shown in Table 2. This temperature correction has been applied to the rain amounts determined by Tucker's correlations.

Table 2. Linear temperature correction to rain rate (Dorman and Bourke, 1978).

$$\text{Rain rate} = (\text{unmodified rain rate}) \times (a + bT + cT^2)$$

T = air temperature in degrees Celsius

| Month     | Coefficients |        |         |
|-----------|--------------|--------|---------|
|           | a            | b      | c       |
| January   | .973         | .0469  | .00382  |
| February  | .941         | .0412  | .00207  |
| March     | .804         | .0404  | .000129 |
| April     | .720         | .0603  | .000042 |
| May       | .489         | .0678  | .000012 |
| June      | .726         | -.103  | .008885 |
| July      | 1.734        | -.2362 | .0119   |
| August    | 1.115        | -.1217 | .00815  |
| September | .548         | .006   | .00514  |
| October   | .671         | .0421  | .002934 |
| November  | .896         | .0701  | .00135  |
| December  | .985         | .0662  | .001148 |

### 3. Converting Rain Amount to Rain Rate

Rain falling during any three hour period varies in intensity. Several studies on the relationship between hourly and "instantaneous" rain rates have been conducted. An early study of Washington, DC by Bussey (1950) found that for any given hour during which rain fell, the instantaneous rain rate was a trace or less 20% of the time. The mean hourly rate was exceeded 35% of the time and "to exceed it by 5 or 6 times for a few minutes was a fairly common occurrence."

Briggs and Harker (1969) compared the average hourly rain rate (clock-hour rain rate) to the frequency of two minute rain rates at Winchcombe, England. The resulting data were used to produce a curve estimating the frequency distribution of two-minute rain rates for any given clock-hour rain rate. This relation can be fit using least squares to the equation,

$$P(RR > nR) = \frac{1}{70} \exp\left[-\frac{n-6.826}{1.605}\right], \text{ where } 0 < n < 11$$

R - clock-hour rain rate (mm/hr)

RR - two-minute rain rate (mm/hr)

P(RR > nR) - probability of two-minute rainfall, RR,  
exceeding nR

The resulting probability of a two-minute rain rate RR, given a clock-hour rain rate, R, is

$$P(RR|R) p(n) = \frac{1}{112.5} e^{-\left(\frac{n-6.826}{1.605}\right)}, \text{ where } 0 \leq n \leq 10$$

and

$$n = \frac{RR}{R}$$

In the application to climatology, if given a series of clock-hour rain rates,  $f_i$ , the corresponding series of two-minute rain rates,  $g_i$ , is

$$g_i(RR) = \sum_n f_i(R) p(R|RR)$$

where the sum is taken over all  $n$  which satisfy the relation  $nR=RR$

The zero rain rate is a special case in which

$$g_i = (0.62) \sum f_i(R).$$

#### 4. Application of the Method

Using this three step process, the "present weather" reports from commercial and U.S. Navy ships have been converted to two-minute rain rates. This method was applied to a data base of standard marine weather observations covering the years 1955 to 1981. The observations are from all hours of the day and night. Observations were grouped into Marsden subsquares (i.e., squares measuring  $1^\circ$  latitude by  $1^\circ$  longitude). This grouping defined the grid interval at which the resulting frequencies were calculated and contoured.

Rain rate maps for the Indian, North Pacific and Atlantic Oceans have been prepared for each of the four seasons: Winter is December to February, Spring is March to May, Summer is June to August, and Autumn is September to November. Maps showing the frequency of observation of rain rates greater than 5, 8 and 15 mm/hr were prepared. It is important to note the distinction between frequency of observation and frequency of occurrence.

The frequency of observation of rain rates greater than 5 mm/hr means that for each location the number of observed rain rate events greater than 5 mm/hr was divided by the total number of observations at that site.

## 5. Results

Seasonal maps from the North Atlantic and North Pacific are shown in Figures 1-8. These maps show the frequency of observation of rain greater than 5 mm/hr. Maps for 8 mm/hr and 15 mm/hr rain rates are included in the appendix. The number of winter observations in the data base is shown in Figures 9-12 for the Indian, North Pacific, and North and South Atlantic Oceans respectively. For these four figures the initial computer drawn isopleths were subjectively smoothed by hand analysis. The number of summer observations is of similar magnitude. Since the Indian and South Atlantic Oceans are data sparse, a single rain rate map for each of these oceans is shown in Figures 13-14. The complete set is included in the appendix.

## 6. Conclusions

It can be seen from the rain rate maps that rain rates greater than 5 mm/hr are observed about one percent of the time in many extratropical oceanic regions. In the low-latitude tropical regions, this percentage increases by several percent and in some Pacific equatorial areas it reaches 10%. These results are consistent with the conclusion that rain rates of 4 mm/hr are exceeded about 1% of the time in extratropical regions (Vanderhill, 1982).

## ACKNOWLEDGMENTS

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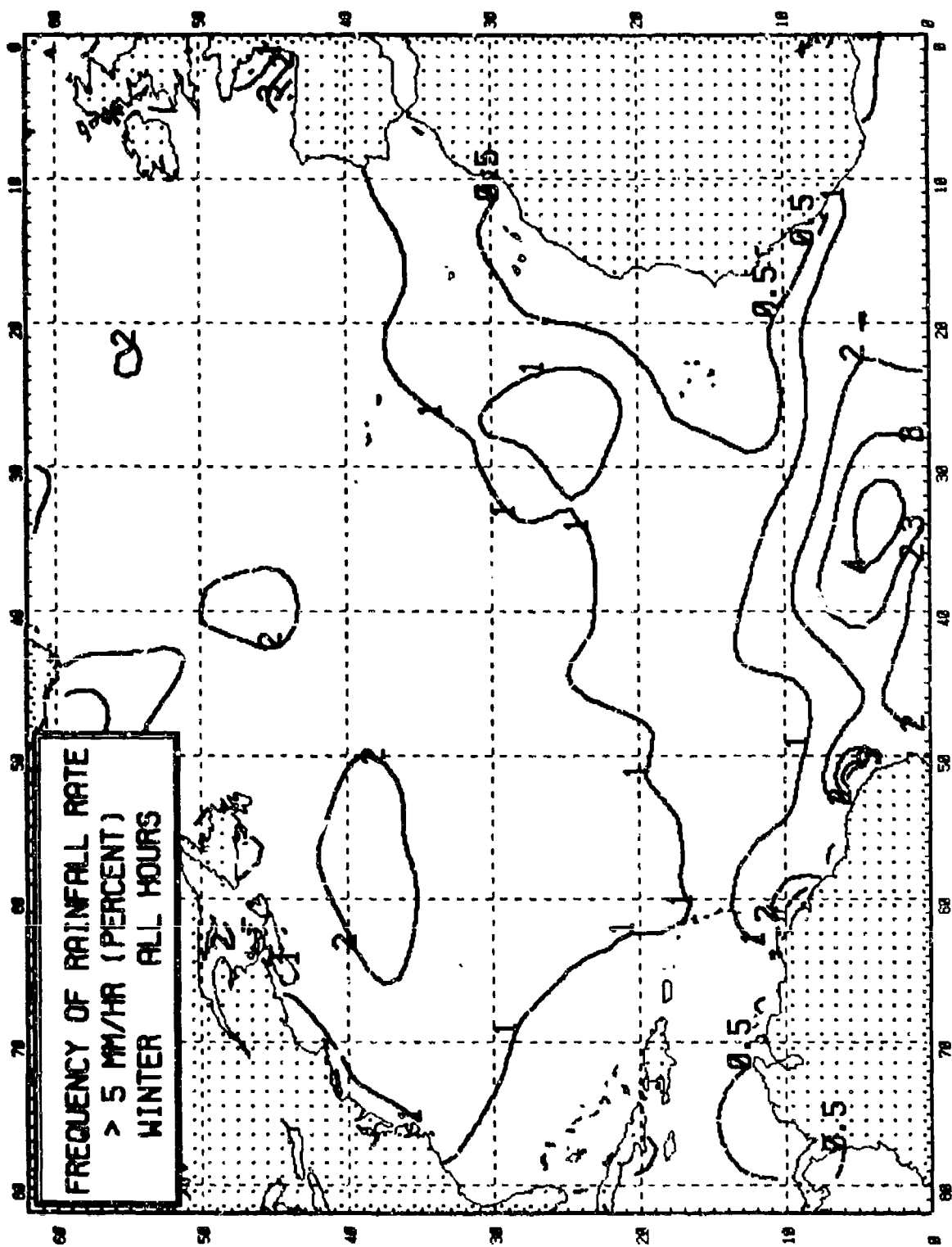


Figure 1

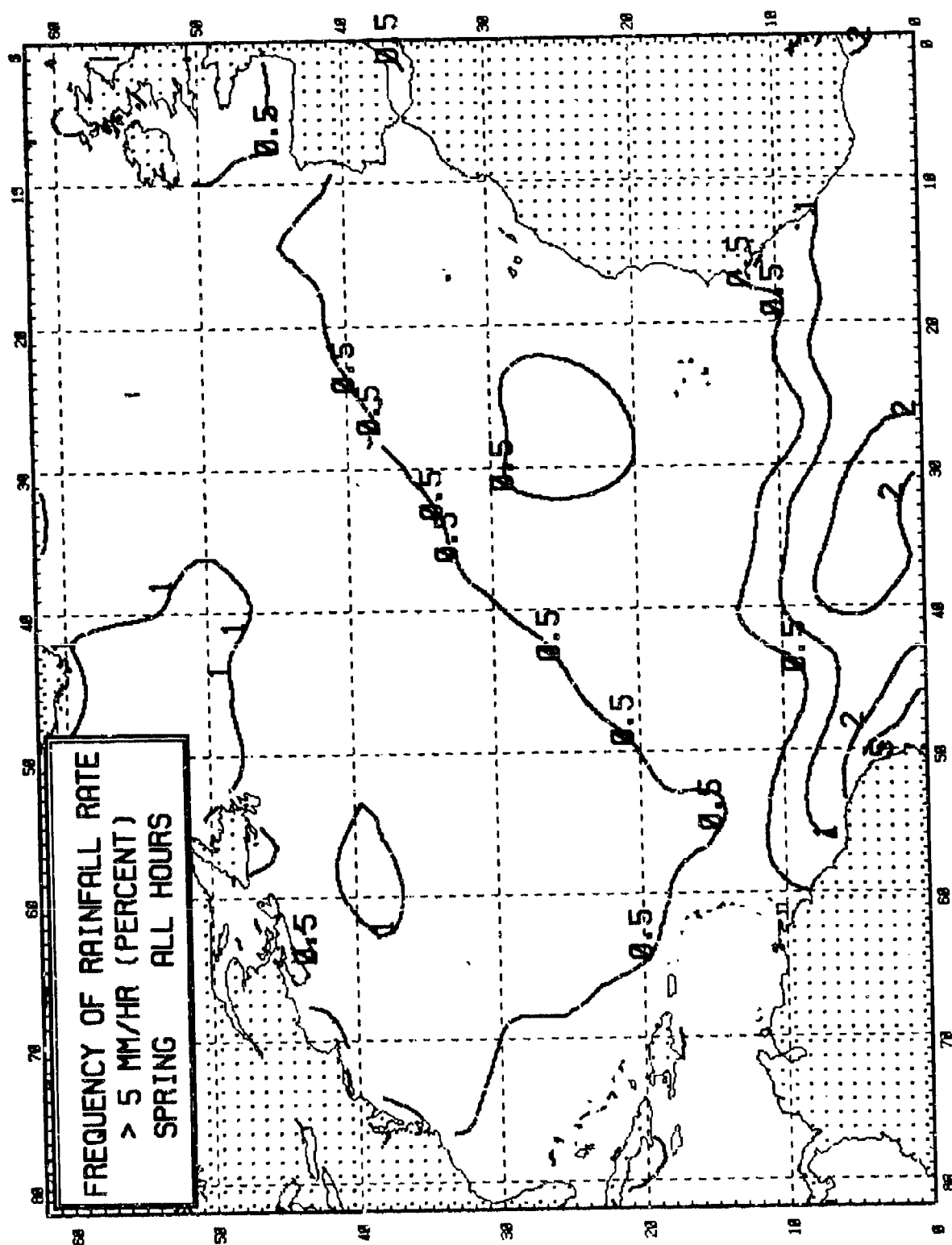


Figure 2

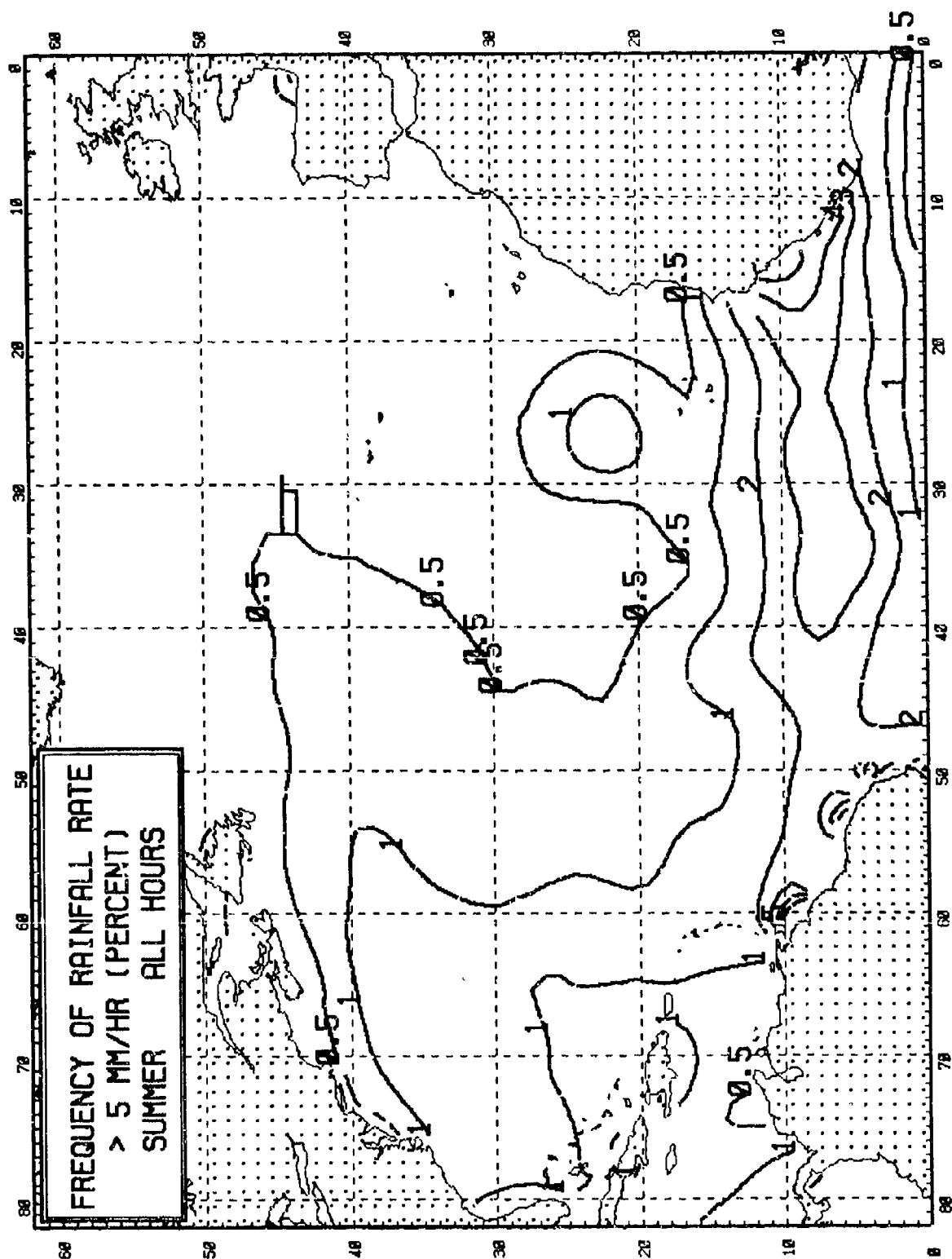


Figure 3

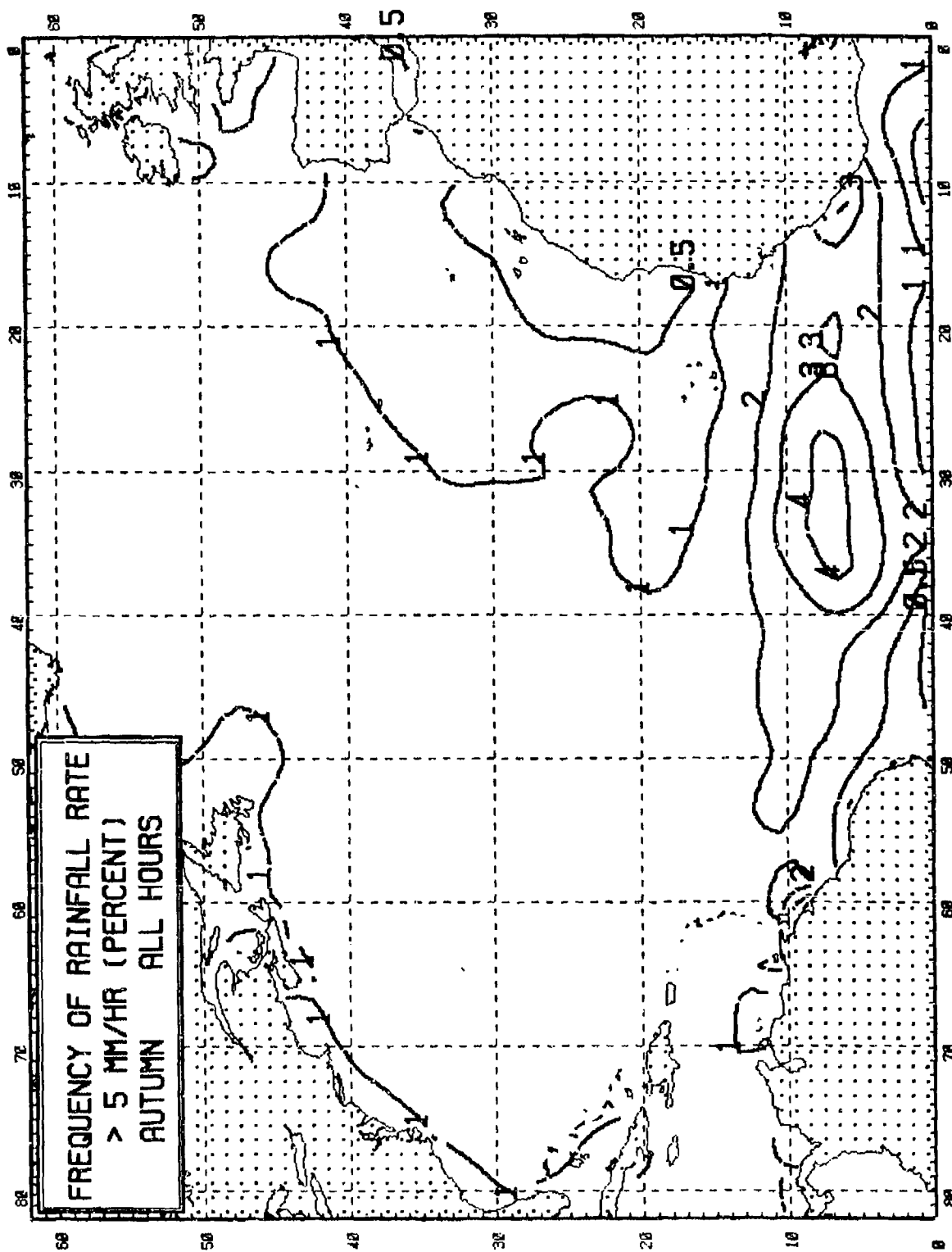


Figure 4

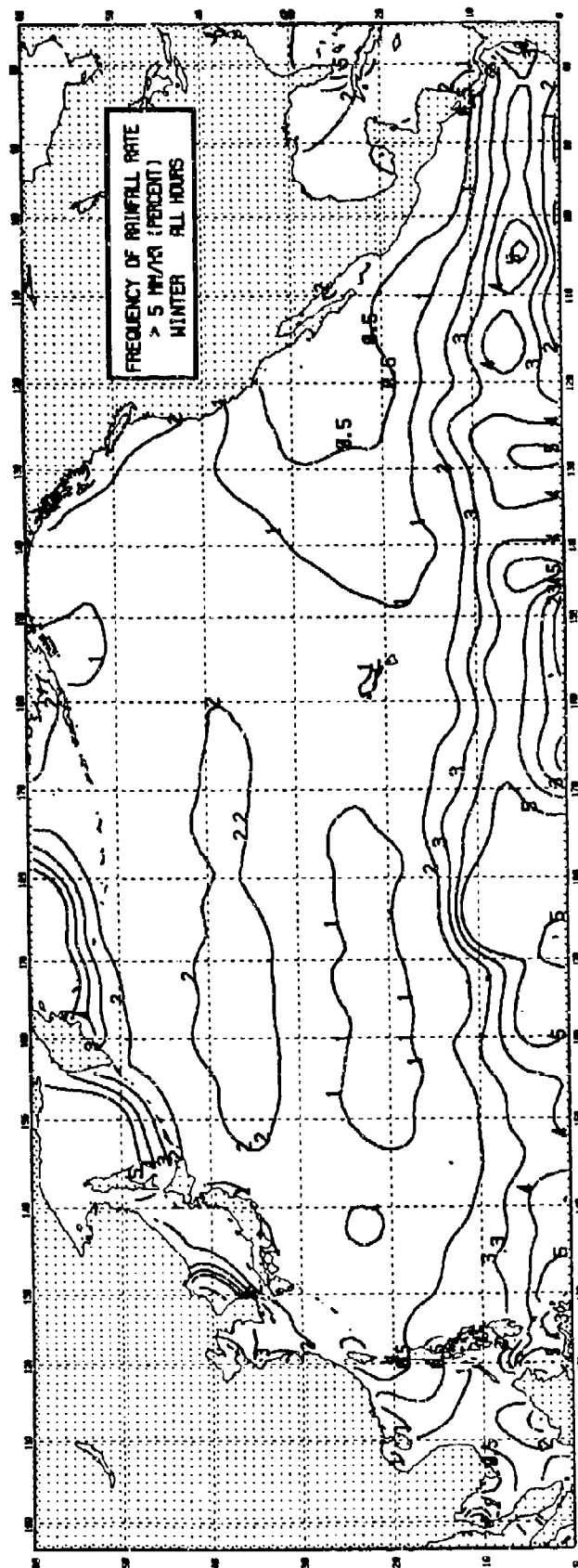


Figure 5

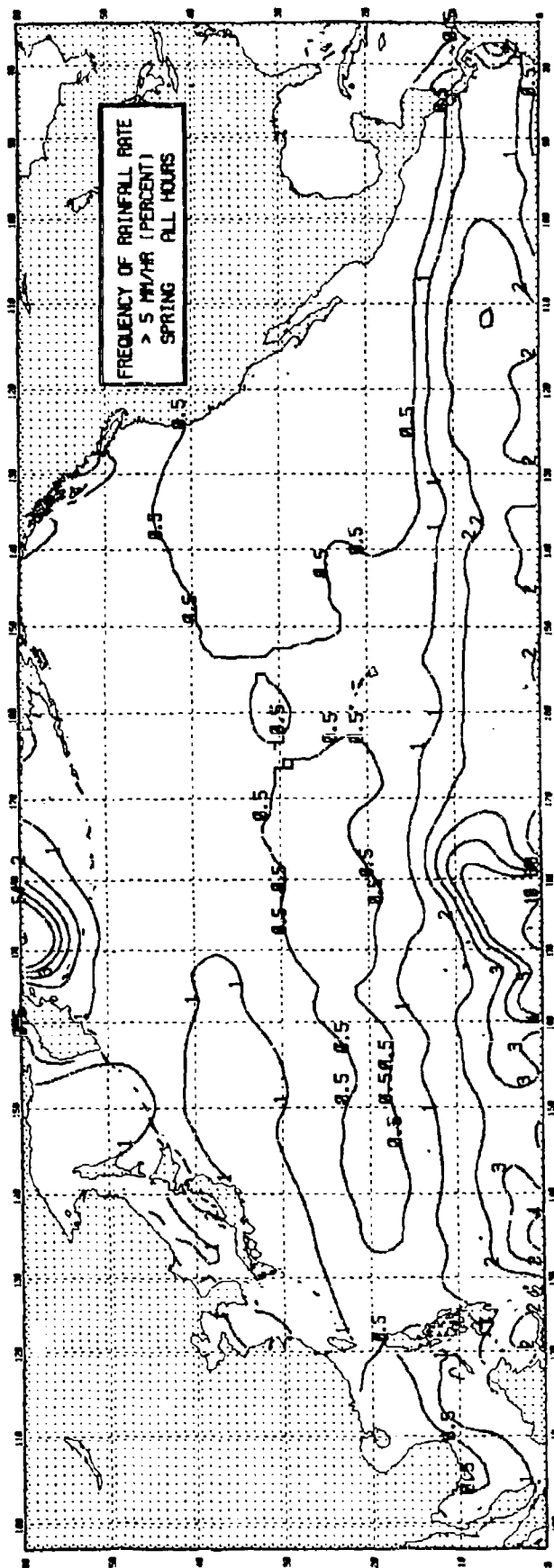


Figure 6

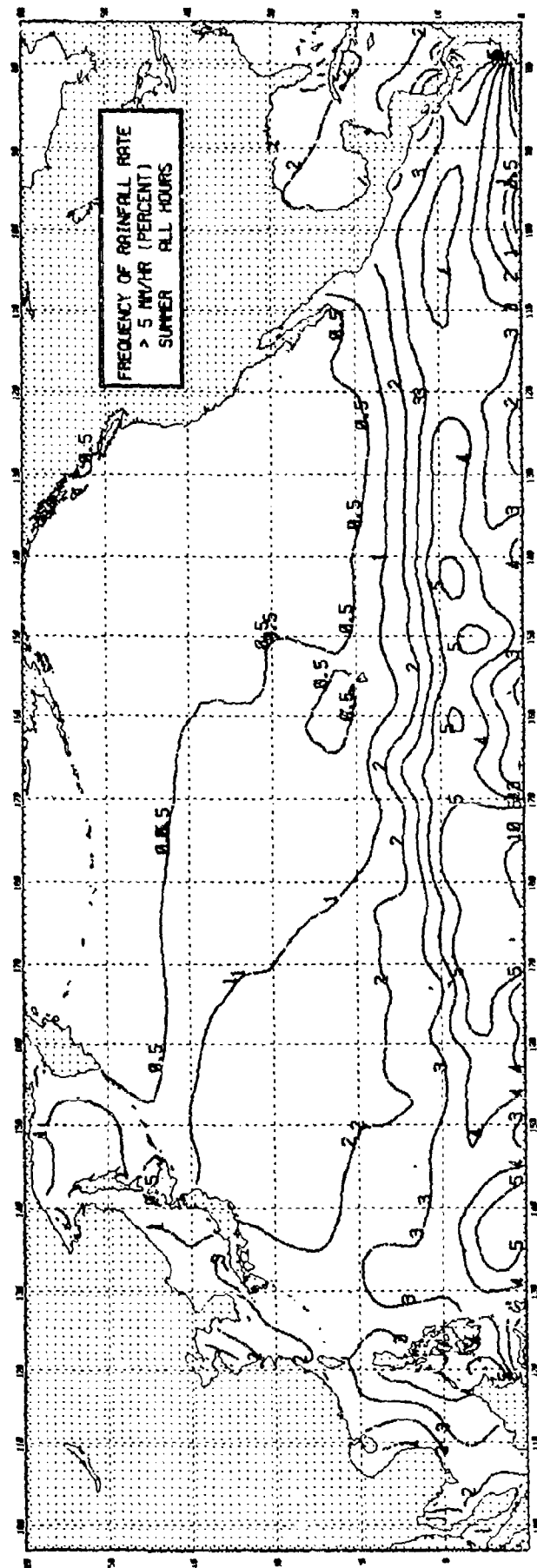


Figure 7

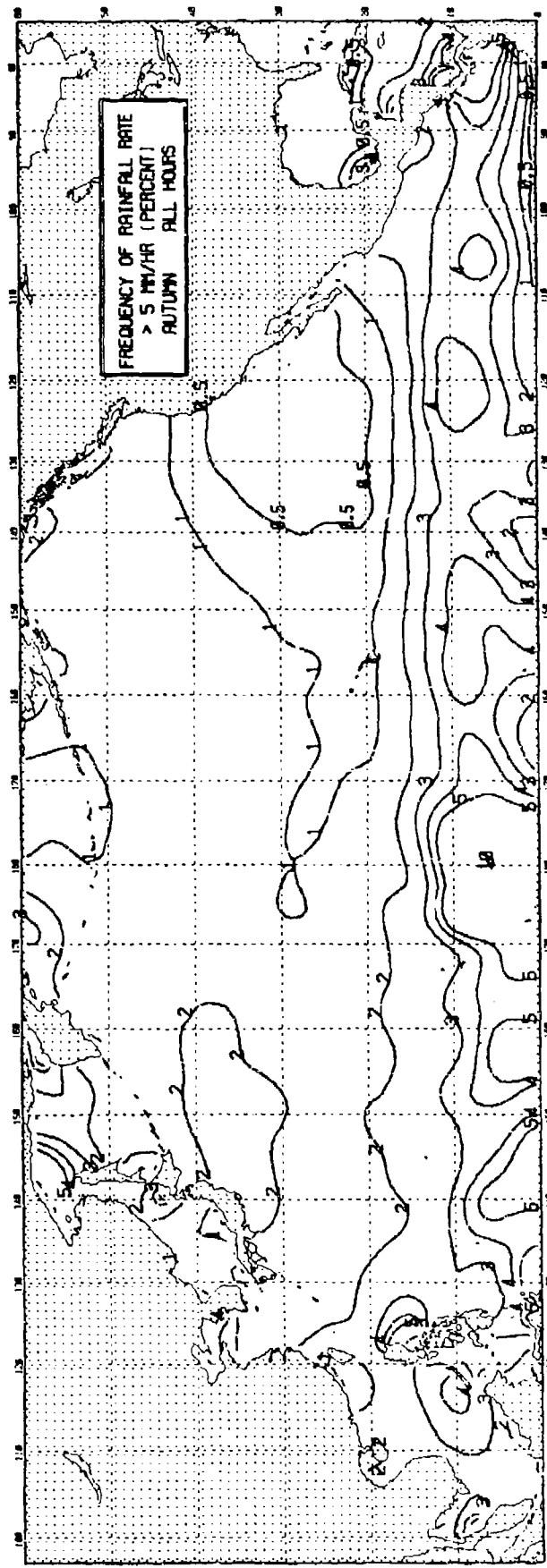


Figure 8

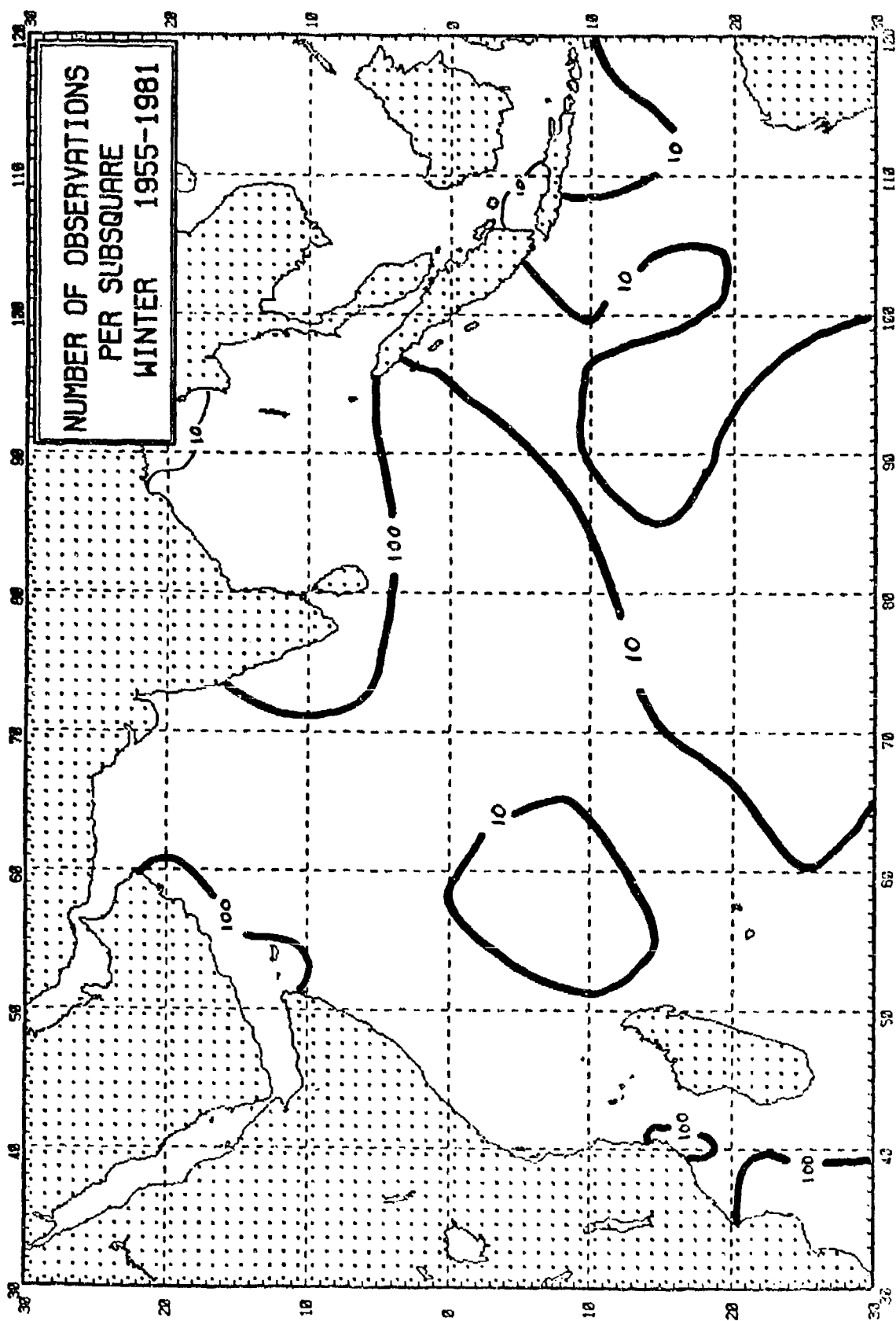


Figure 9

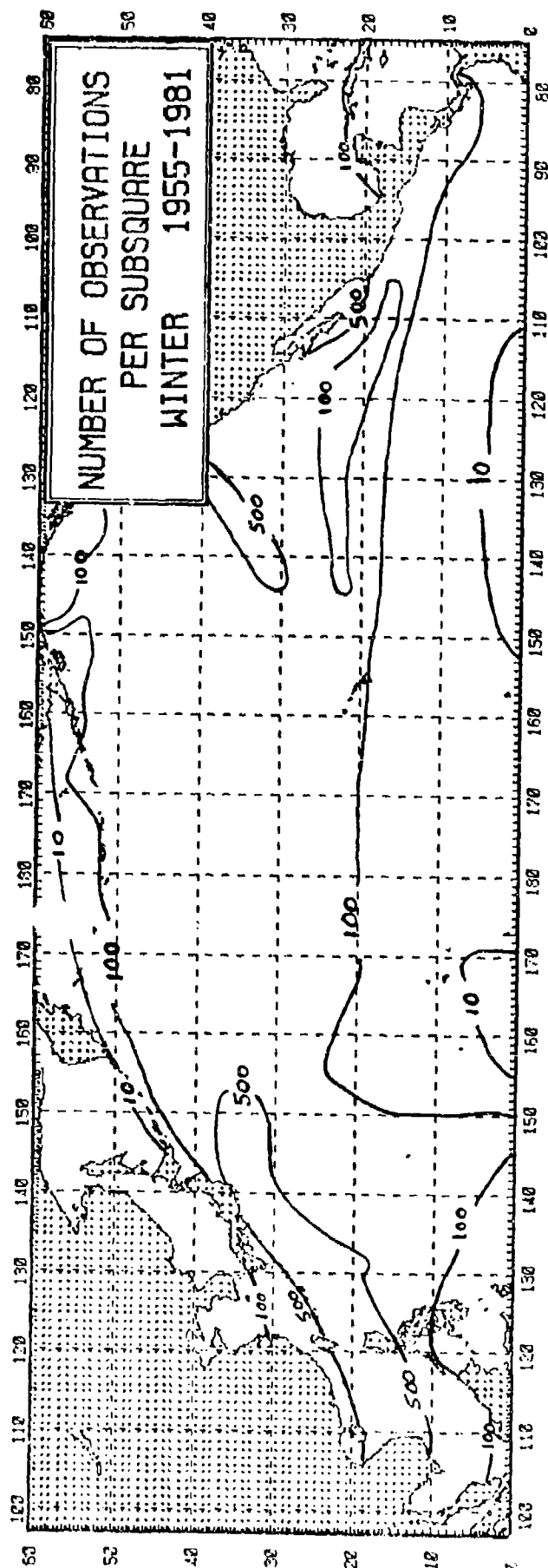


Figure 10

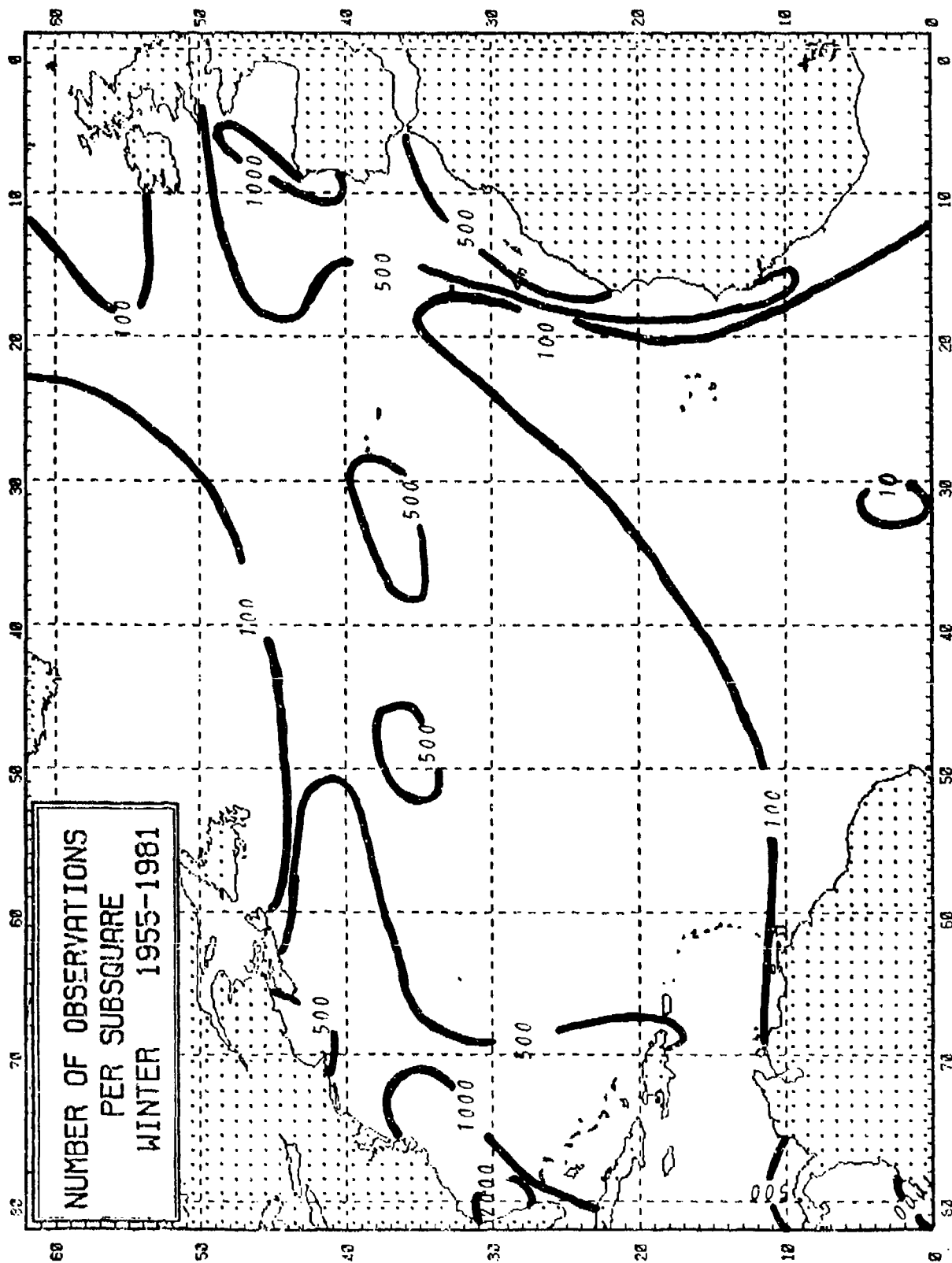


Figure 11

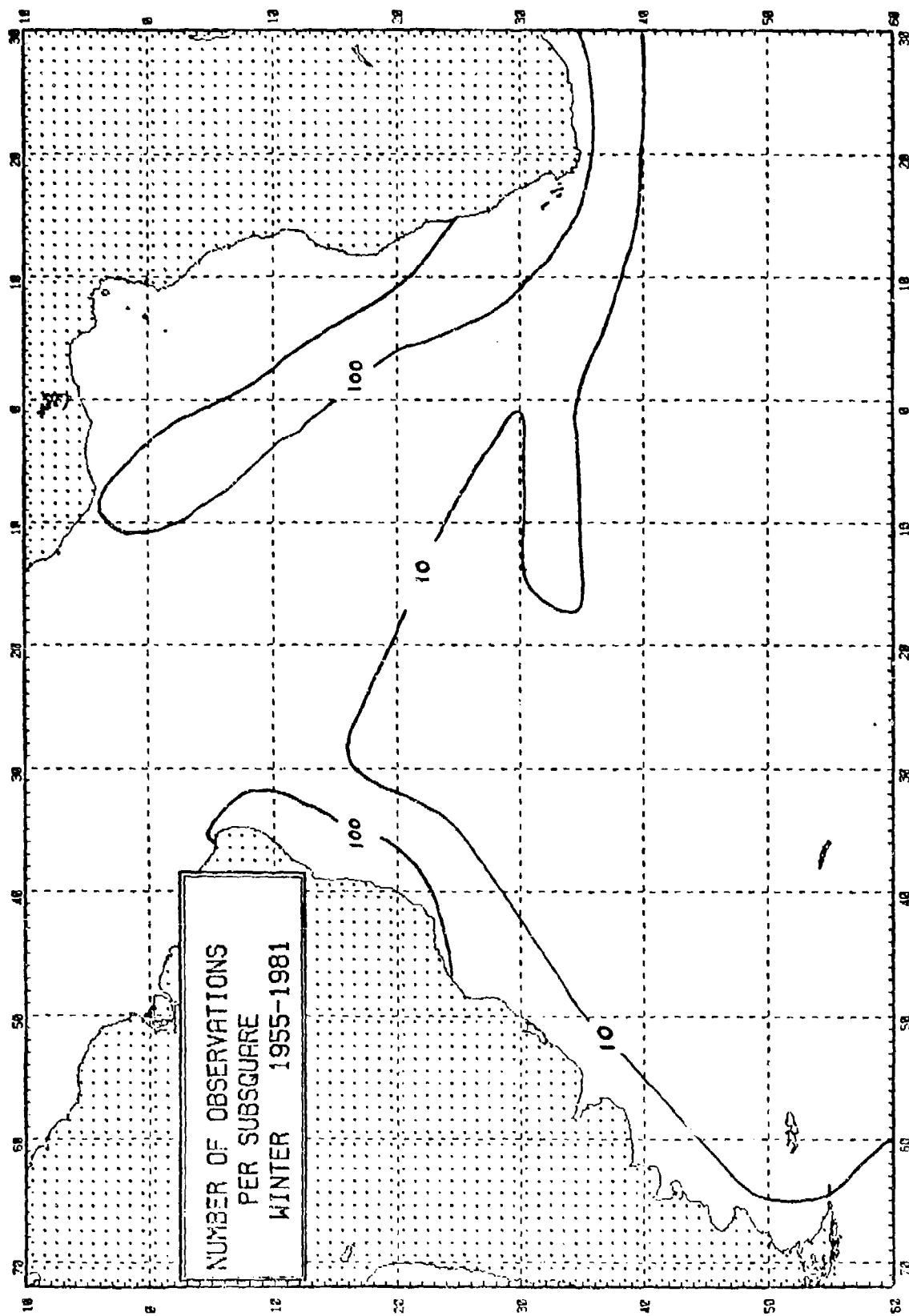


Figure 12

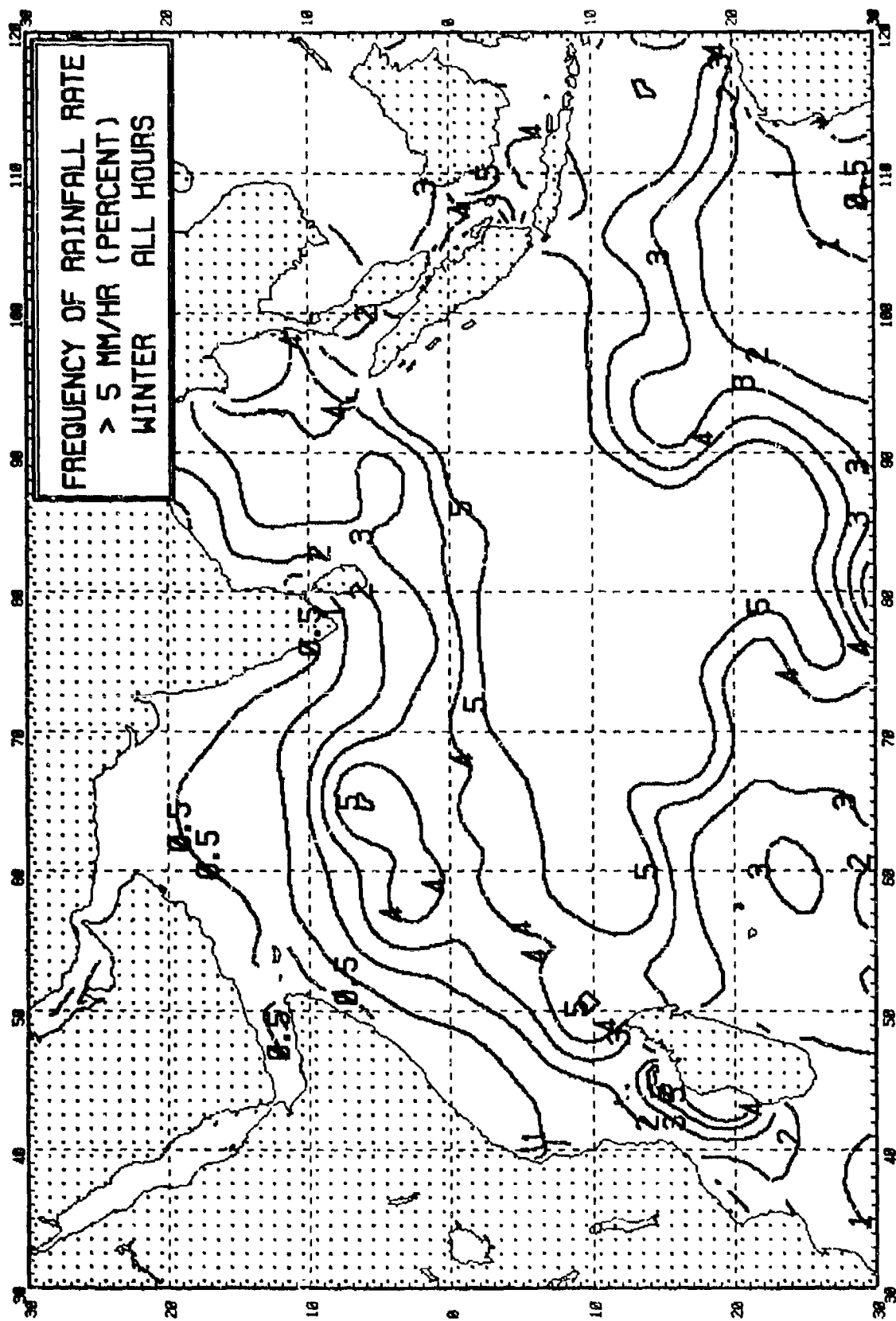


Figure 13



## APPENDIX

### RAIN RATE MAPS - ALL OCEANS AND SEASONS

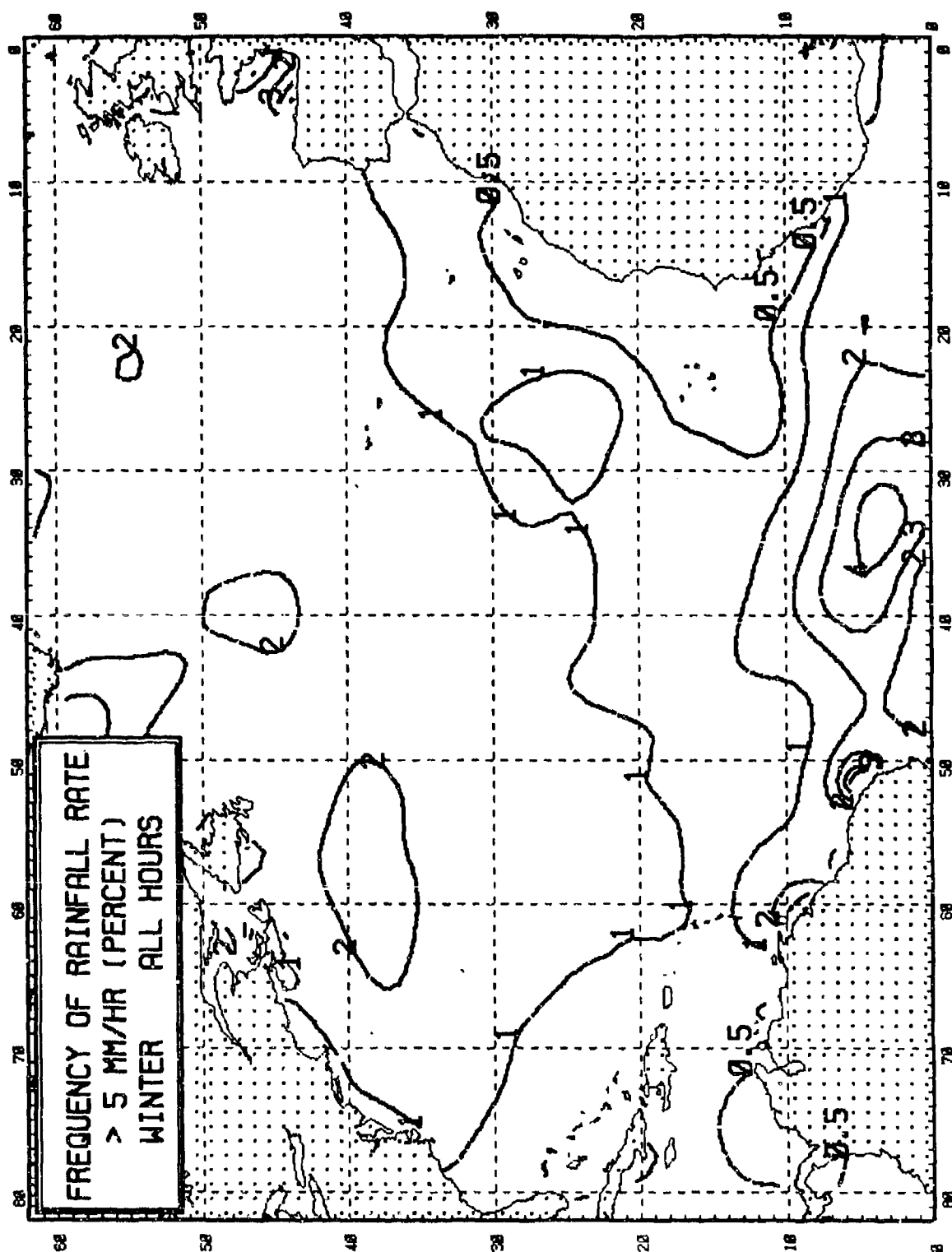
Maps in this appendix are sequenced in groups by ocean region, season within region, and frequency of rainfall rate within season.

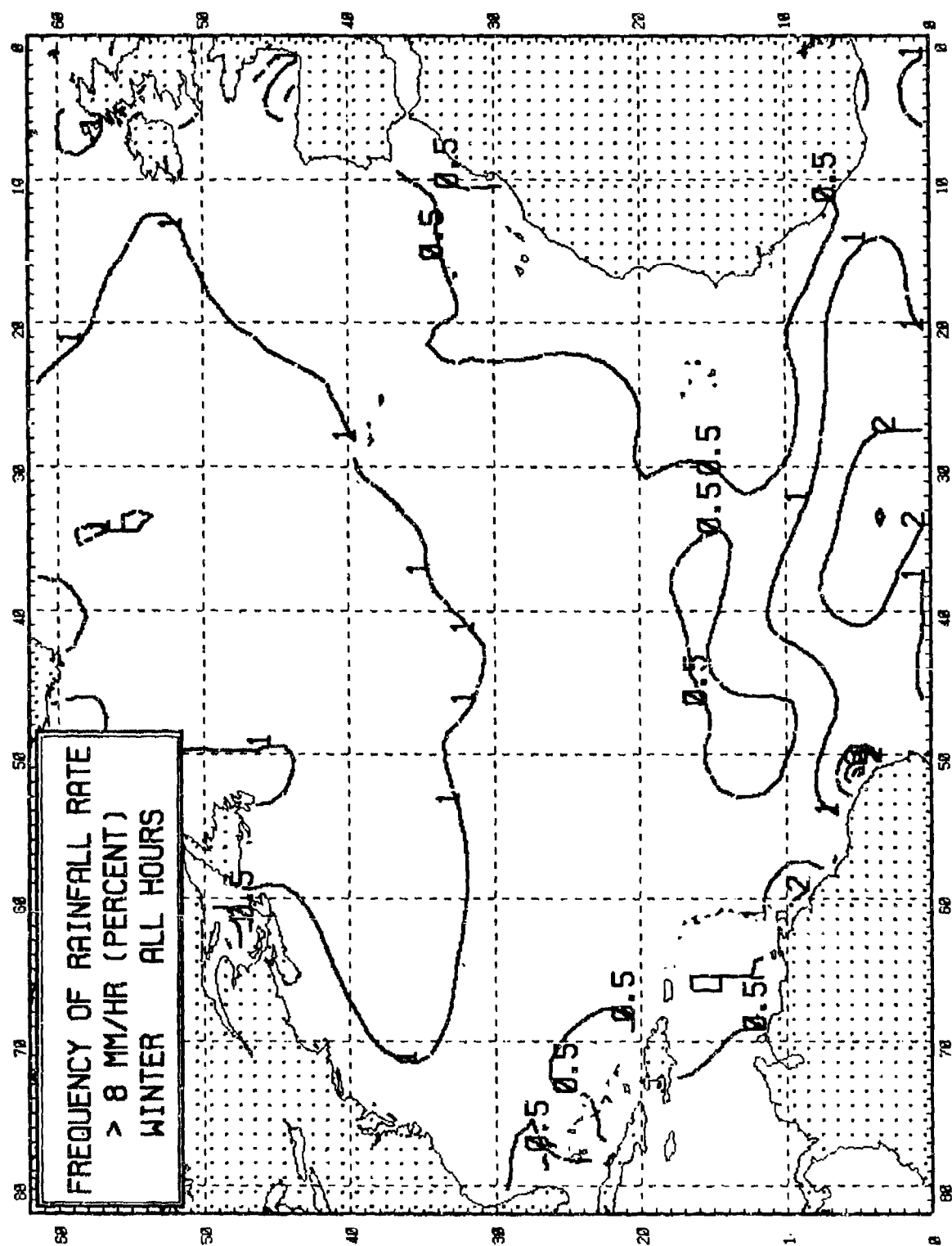
Ocean sequence -- N. Atlantic, N. Pacific, Indian, S. Atlantic.

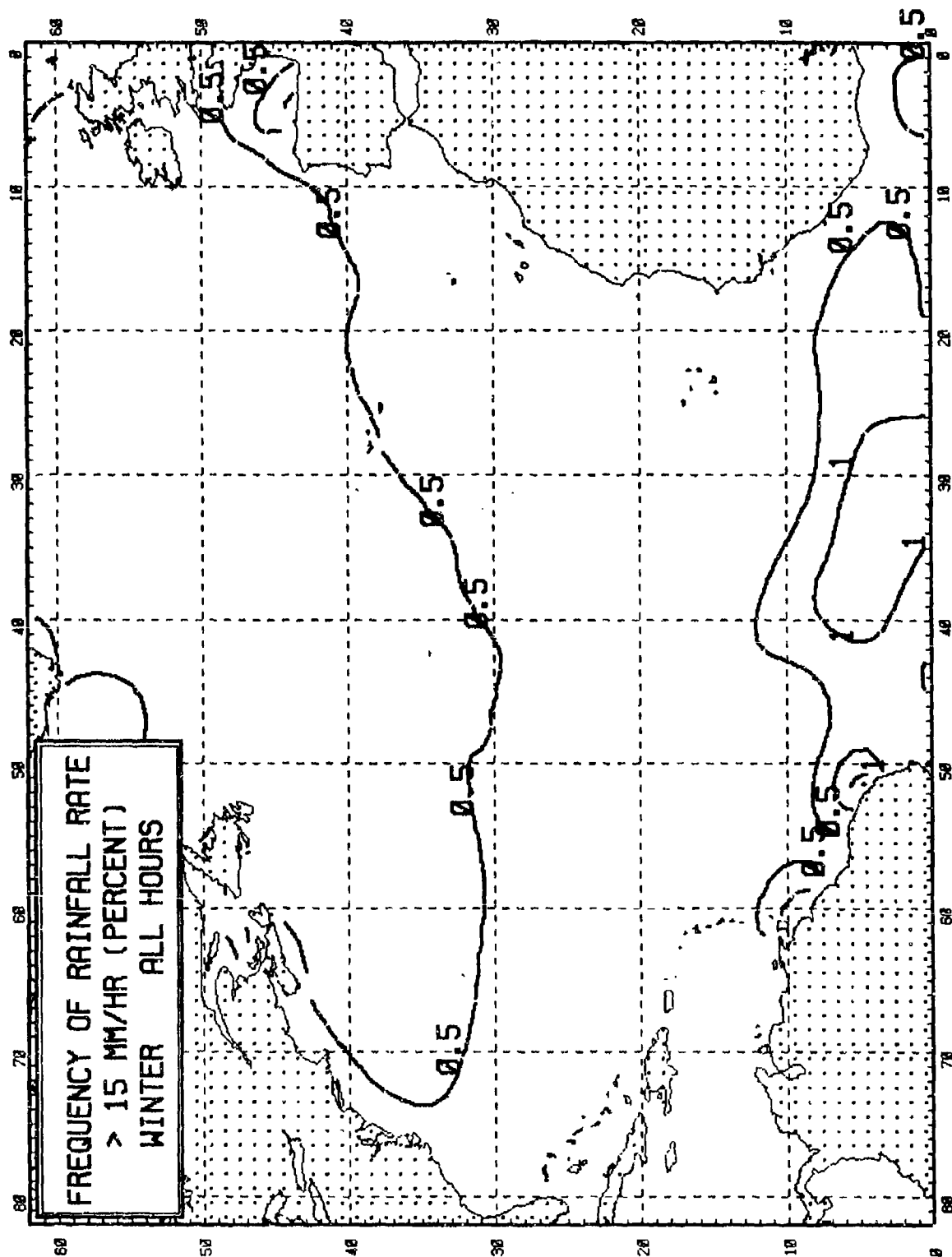
Season sequence -- winter, spring, summer, autumn

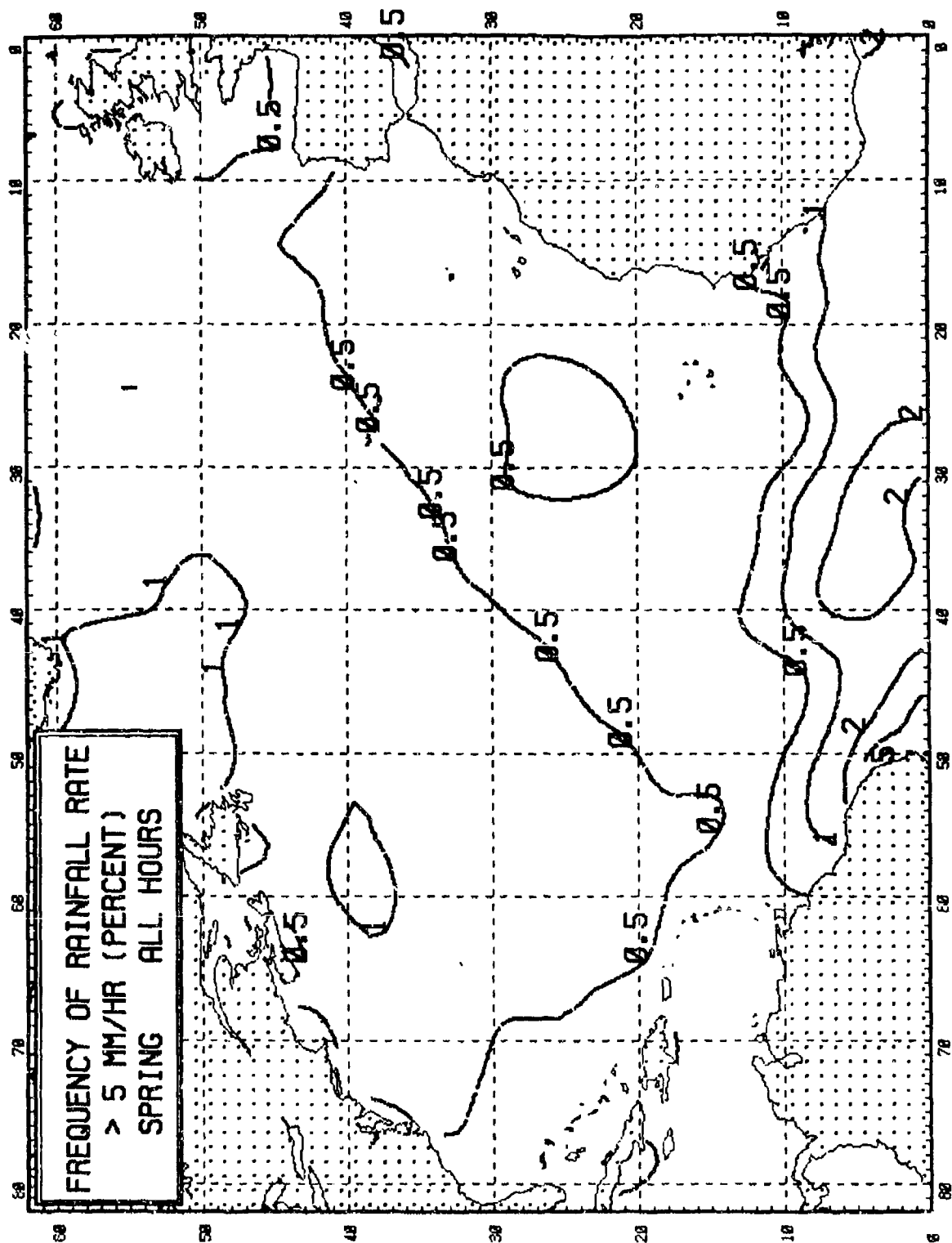
Rate sequence -- greater than 5, 8, 15 mm/hr (percent)

The final group of maps shows "number of observations per sub-square" for winter and summer in the ocean sequence above.

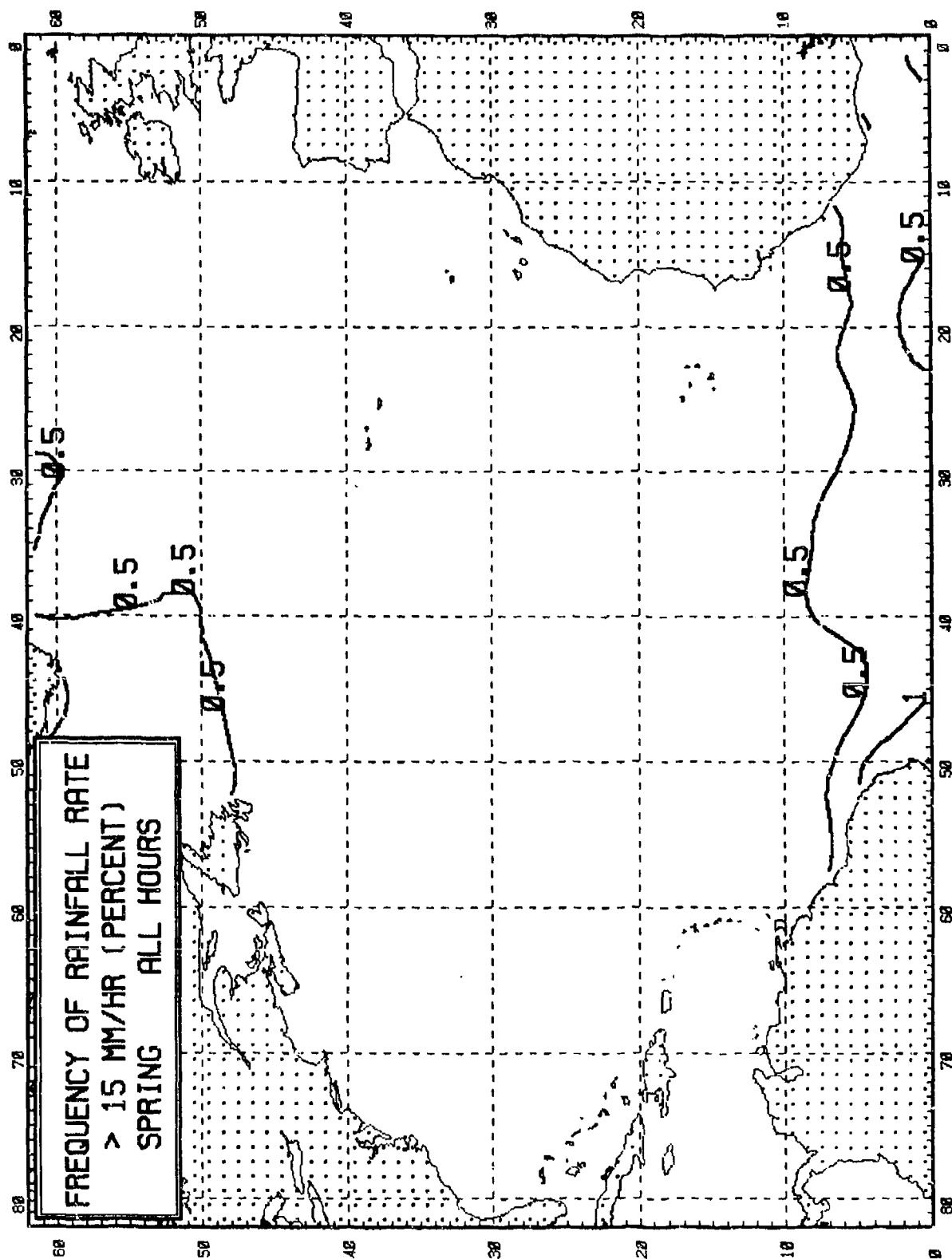


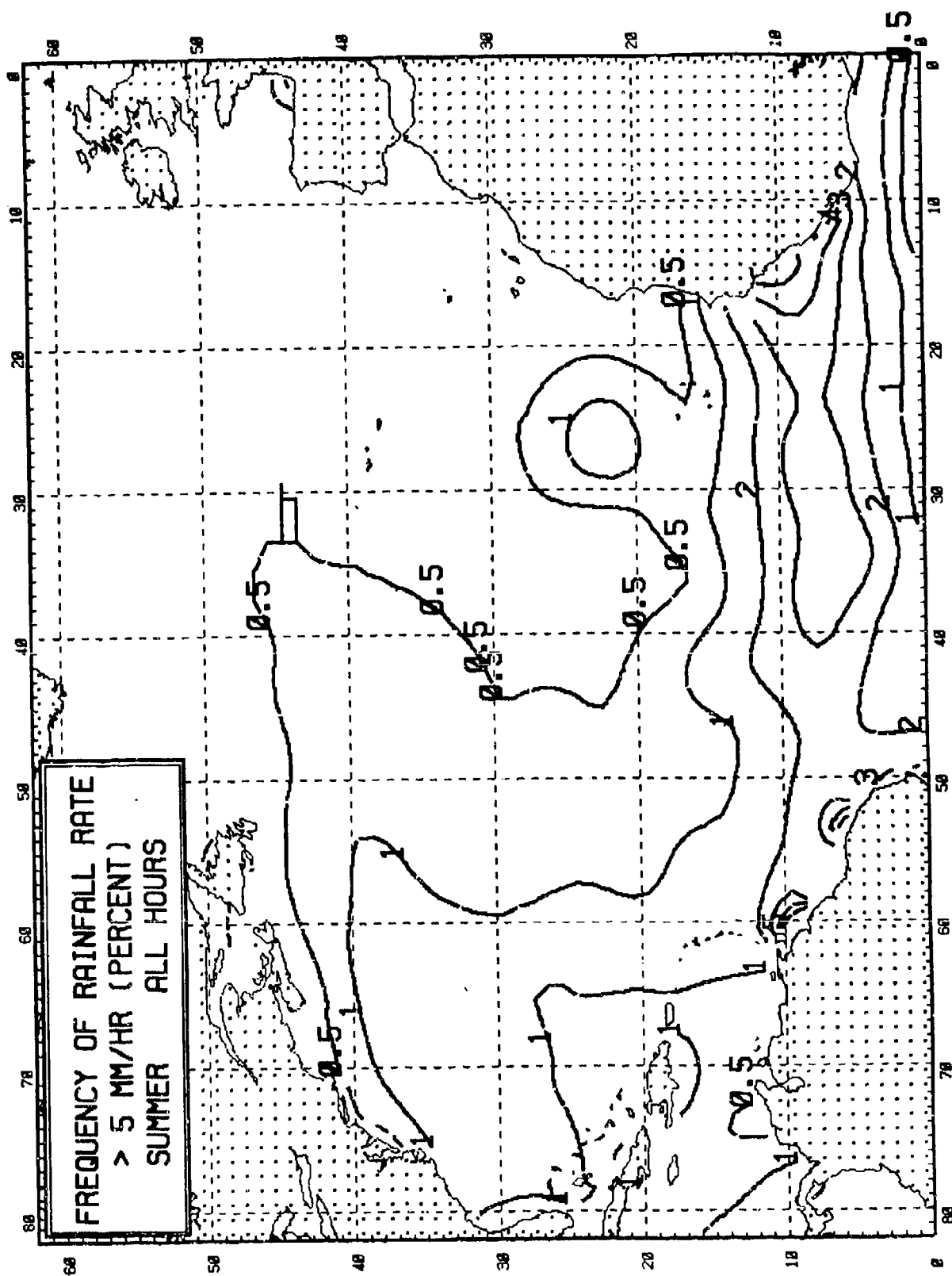


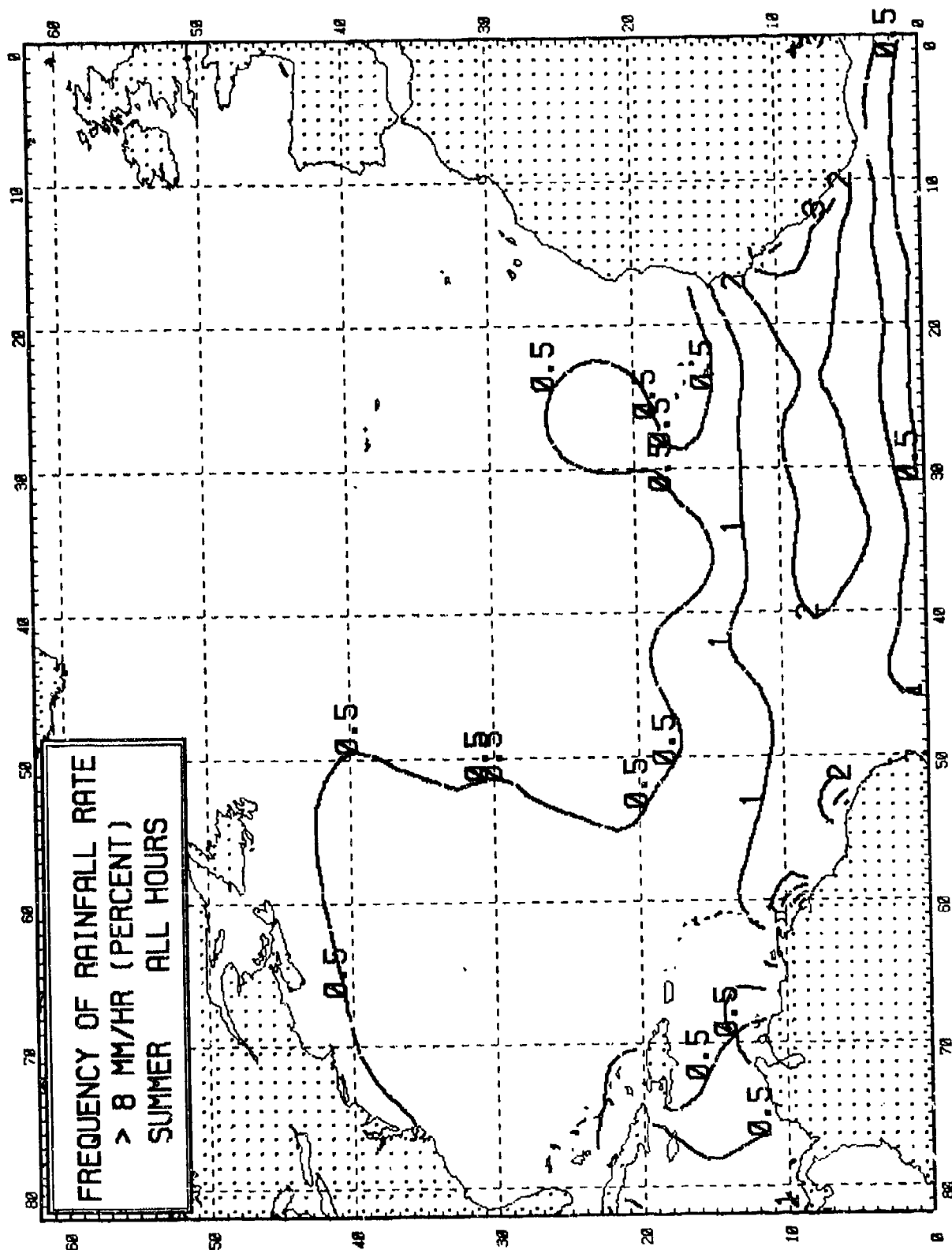


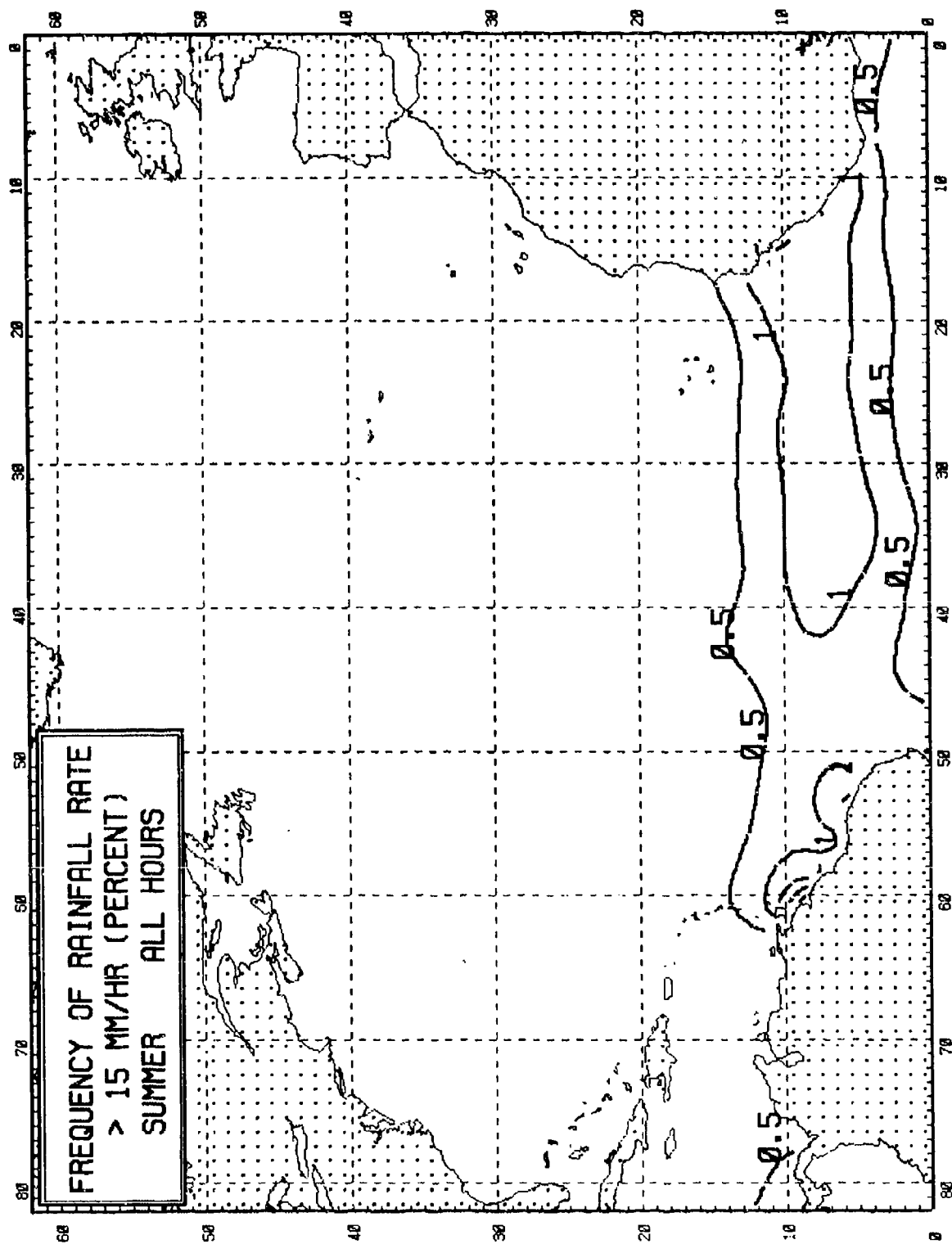


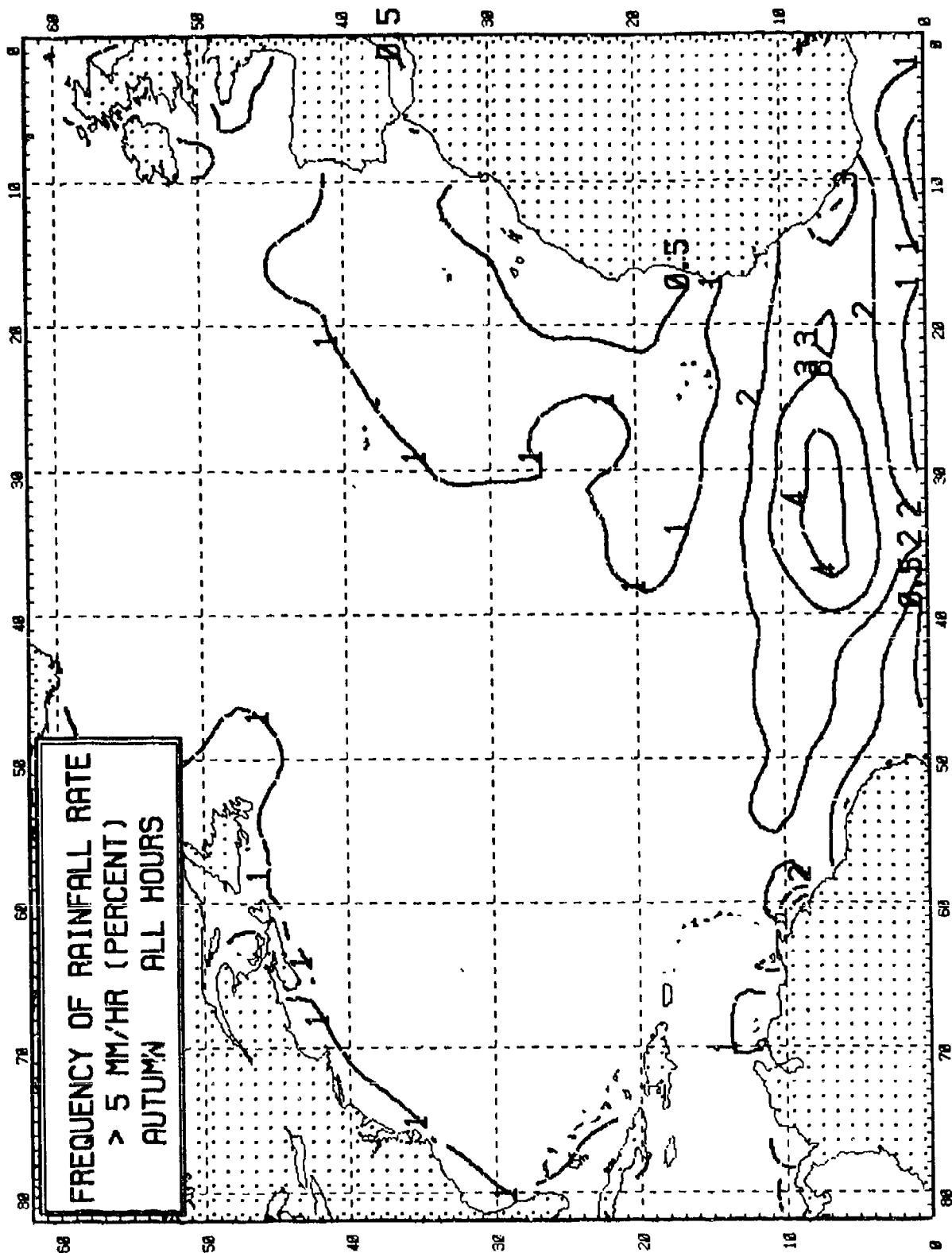


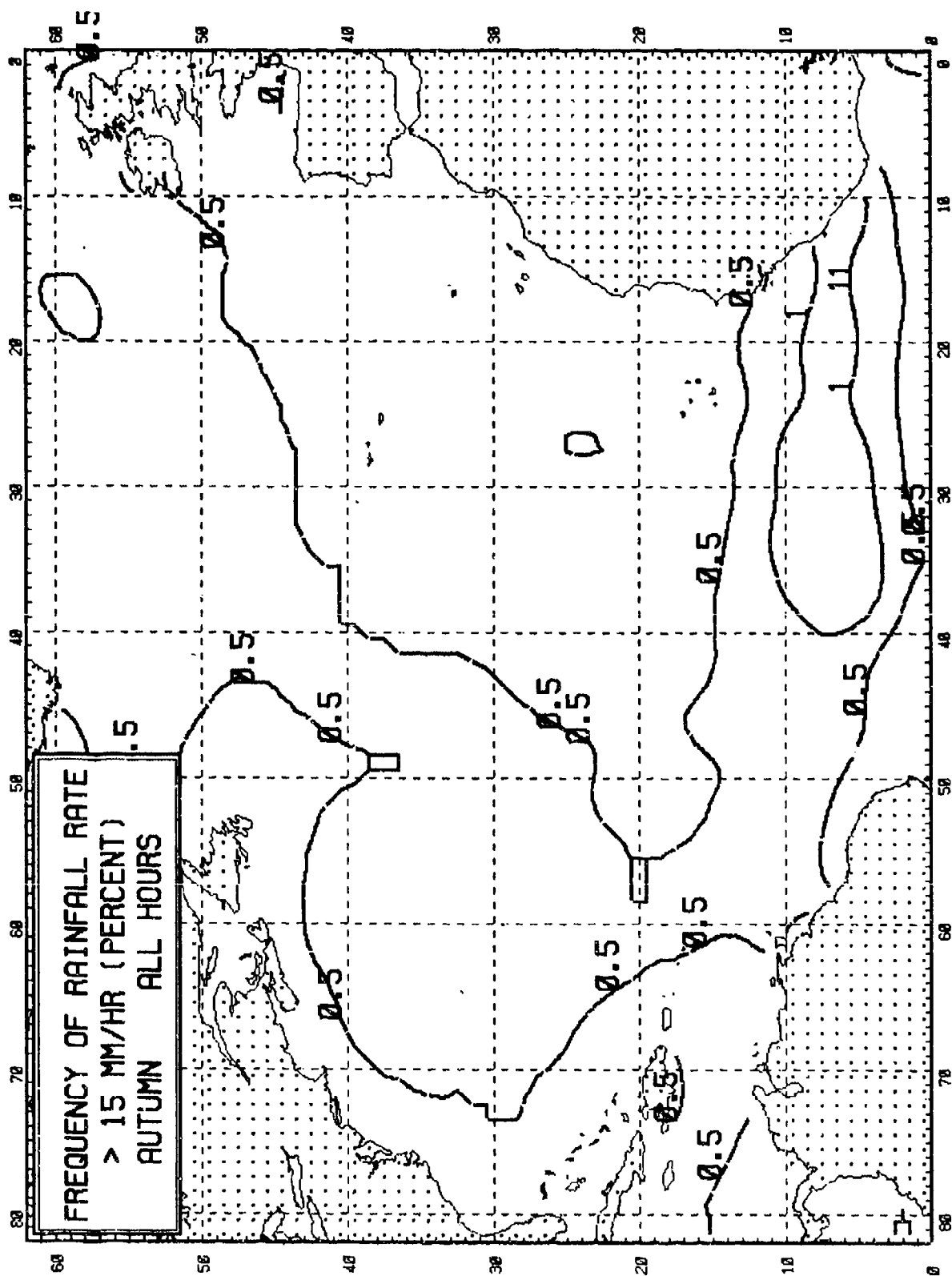


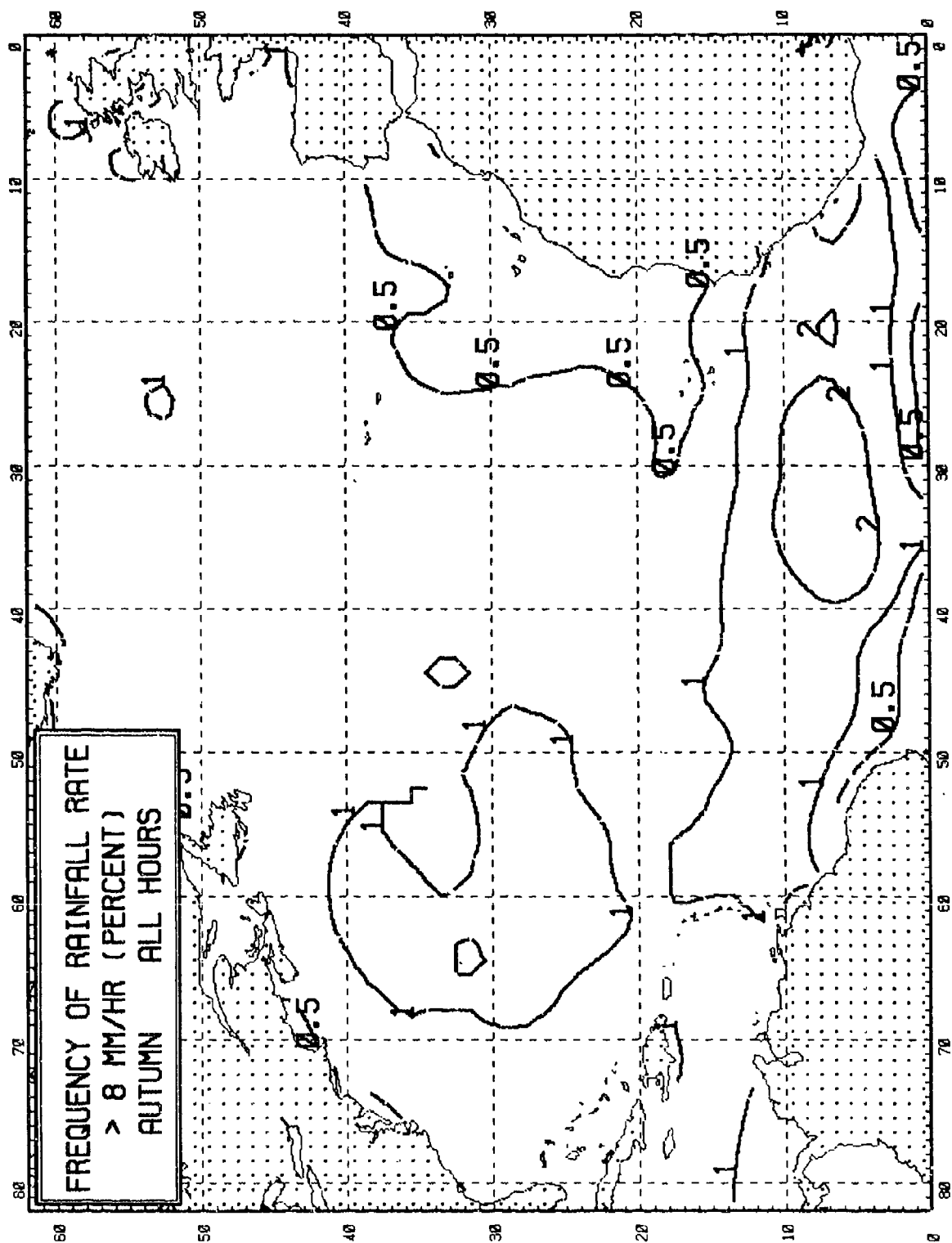


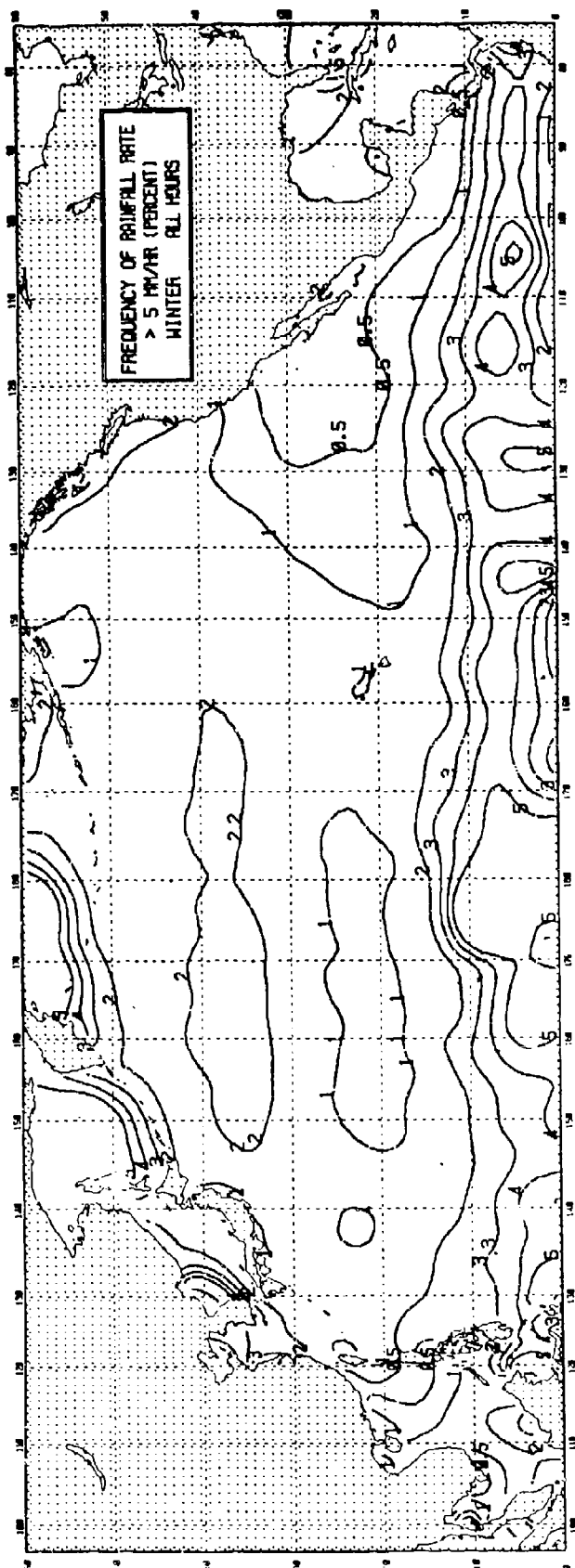


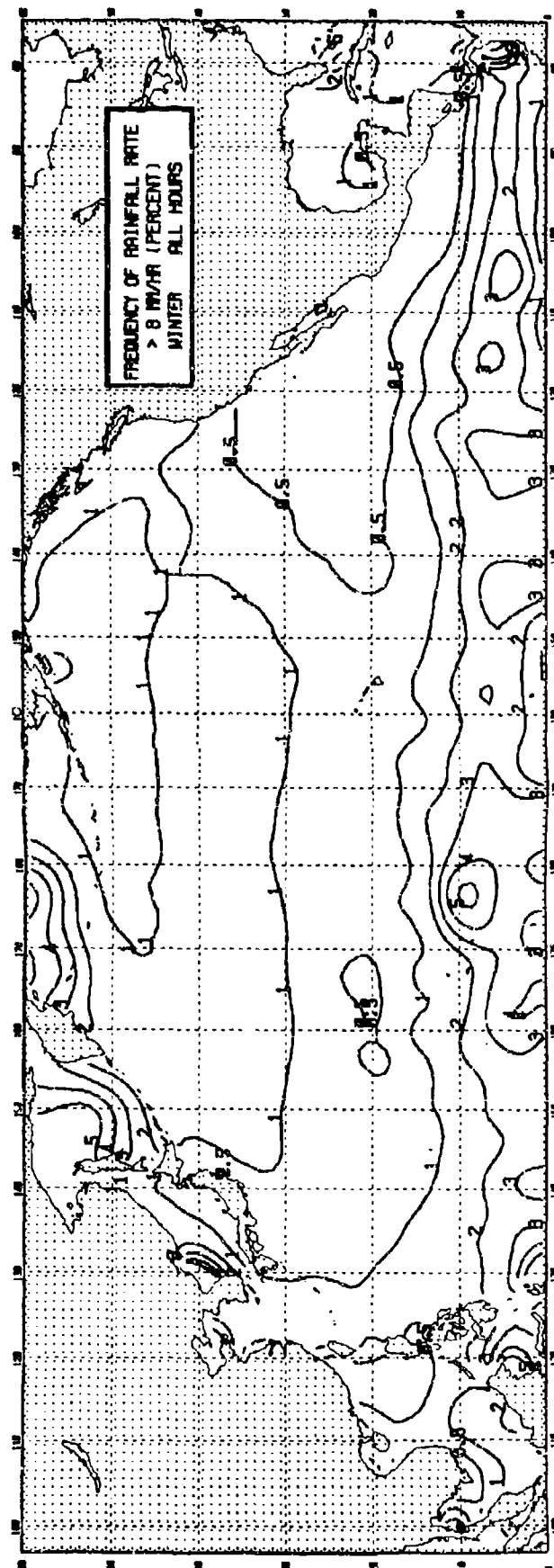


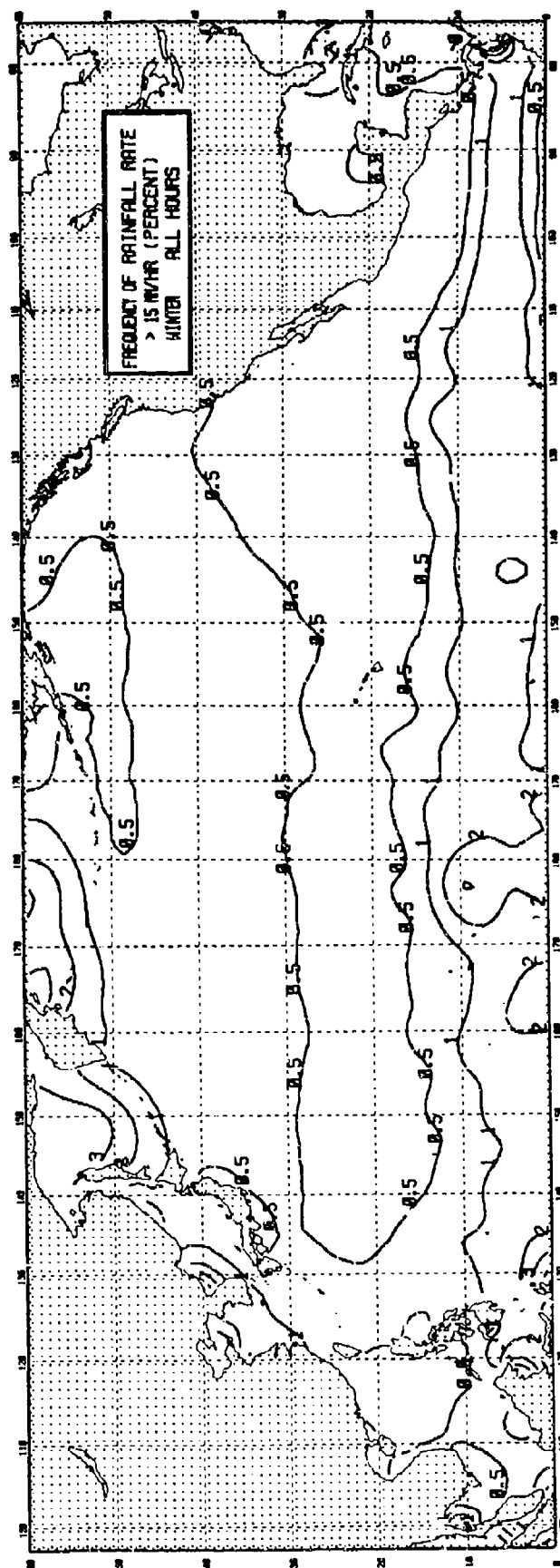


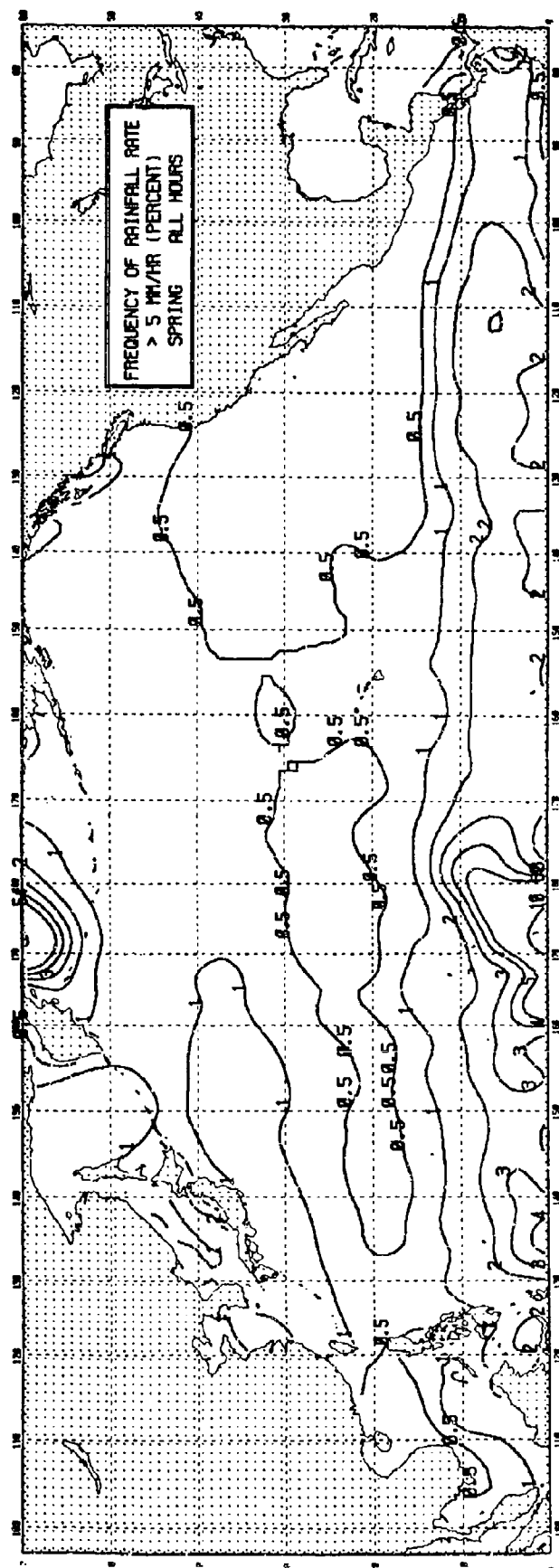


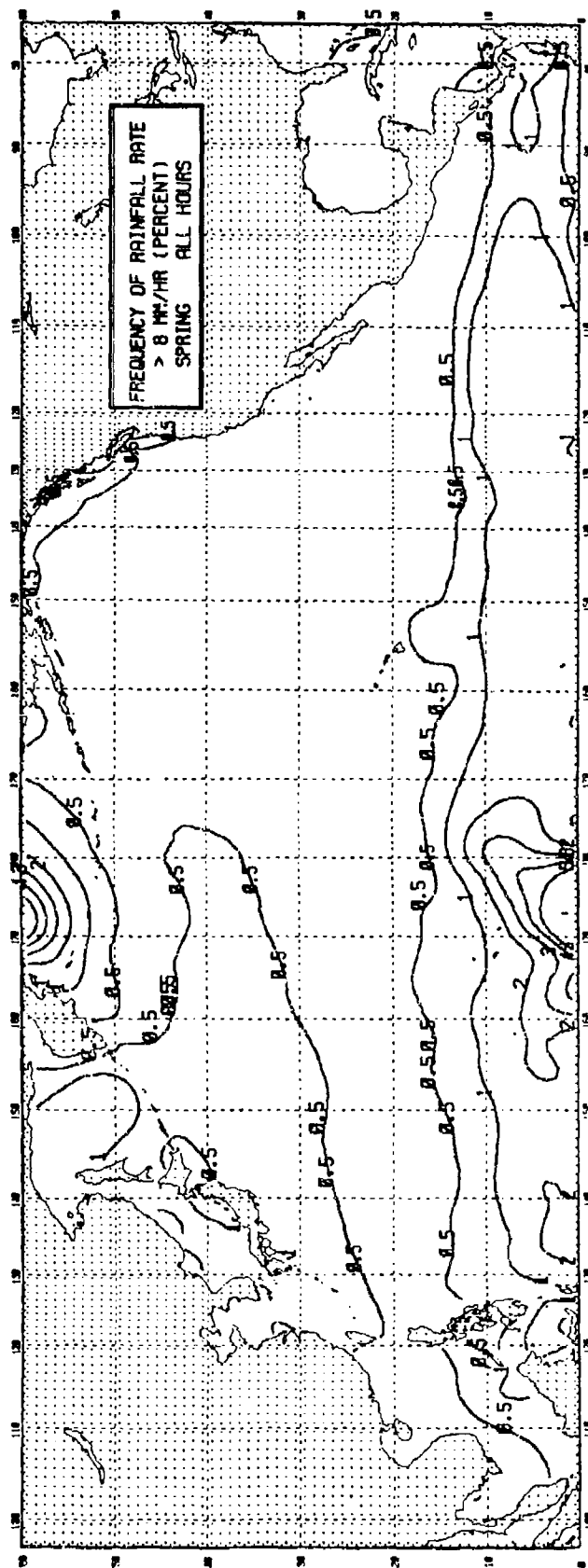


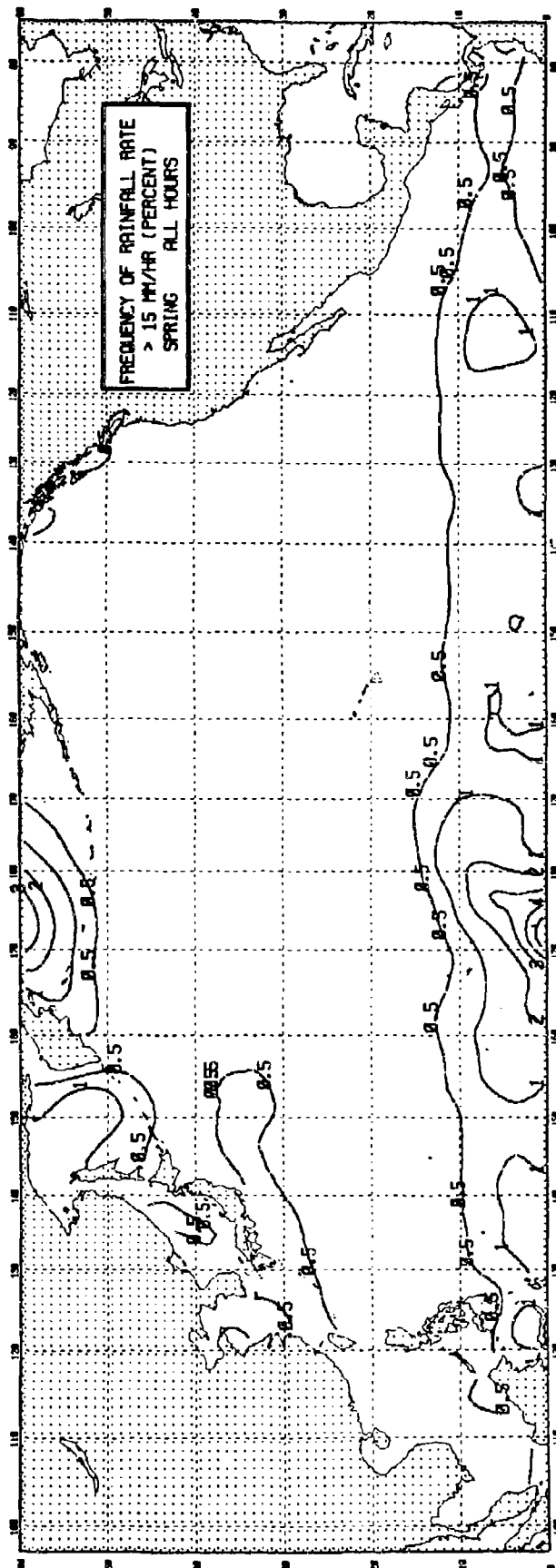


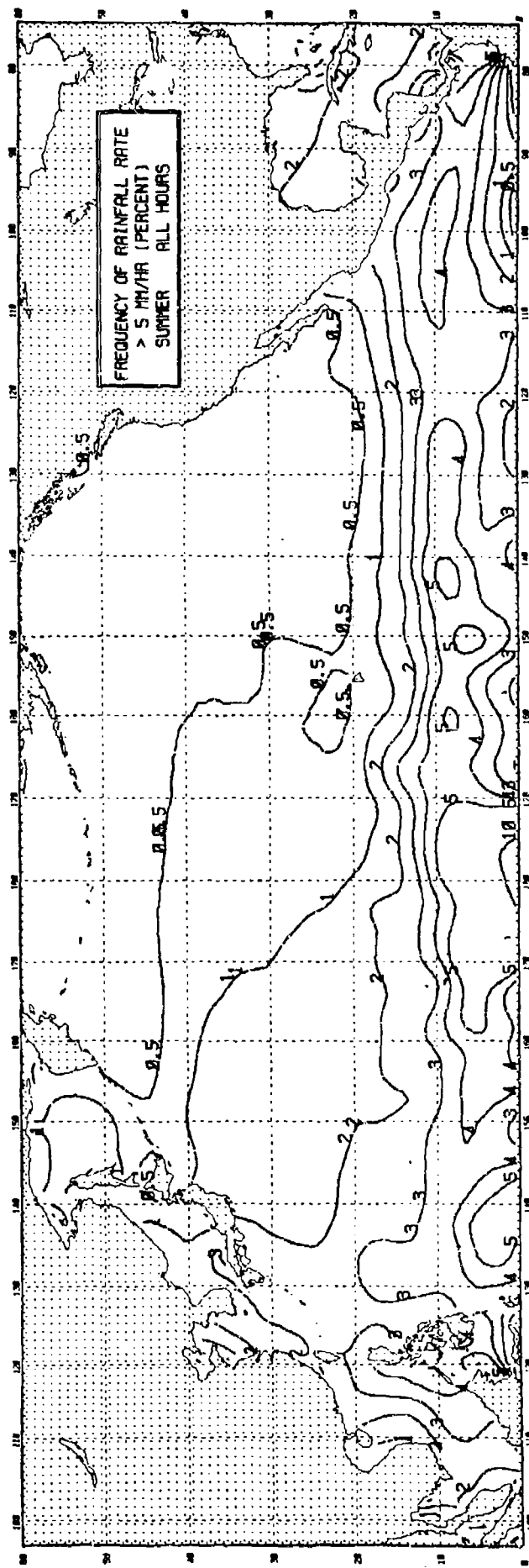


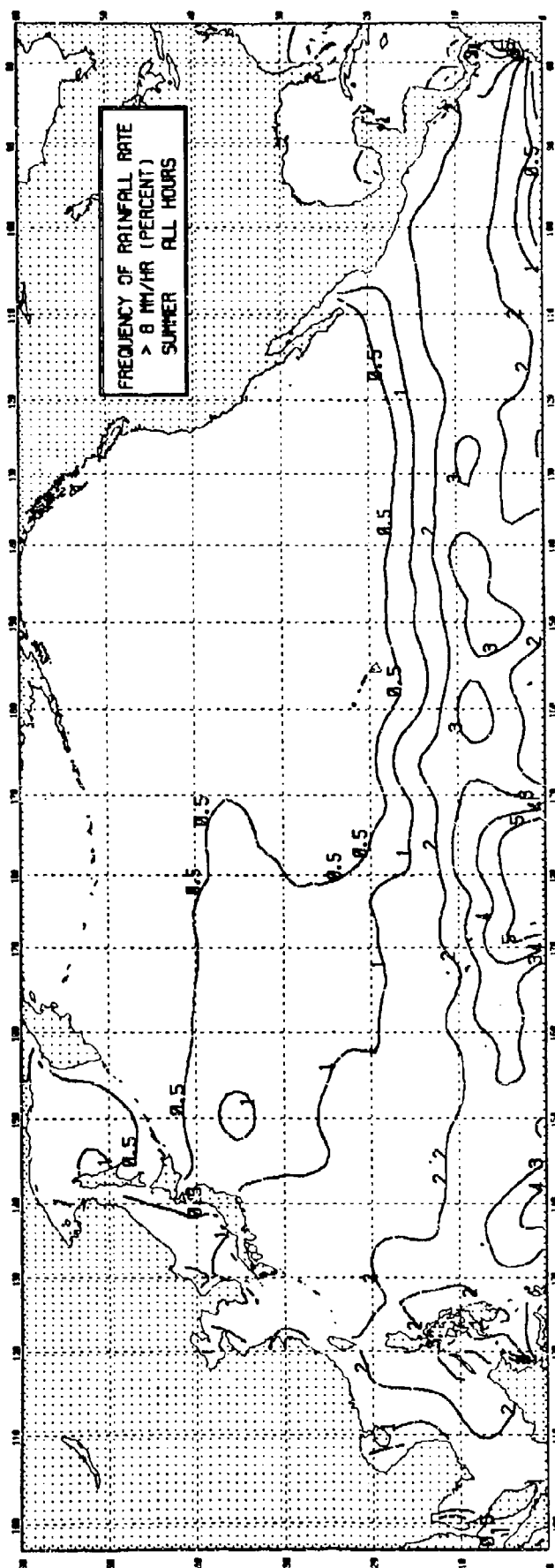


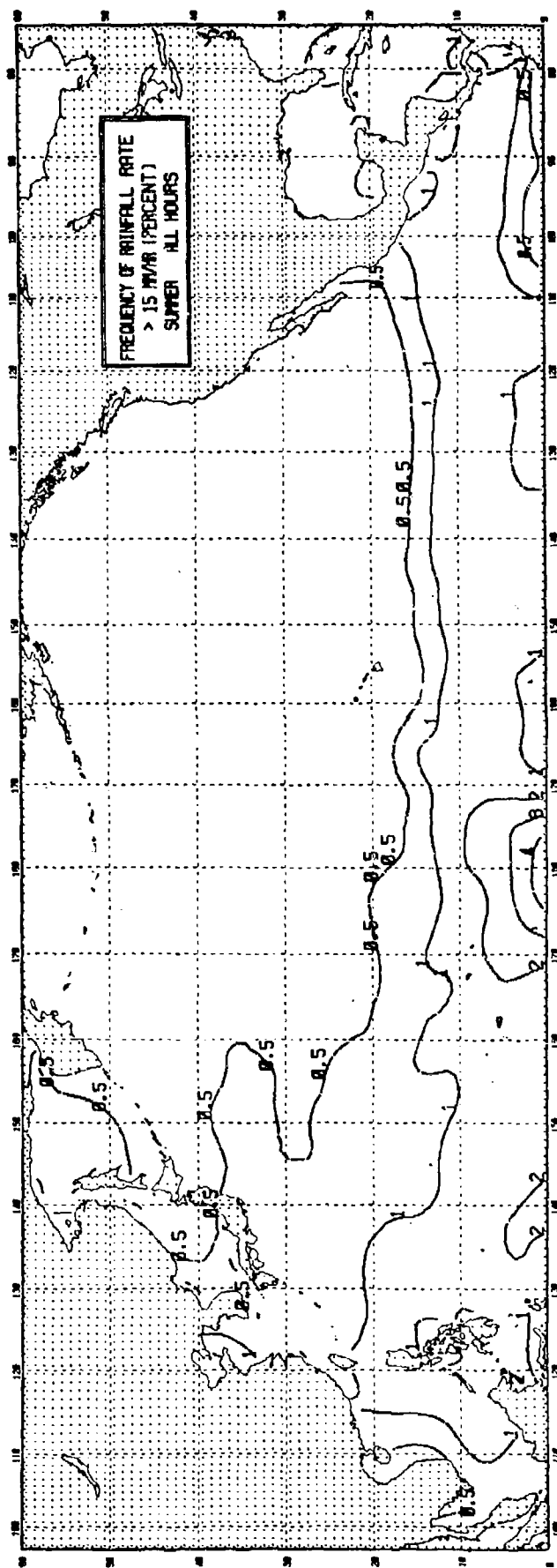


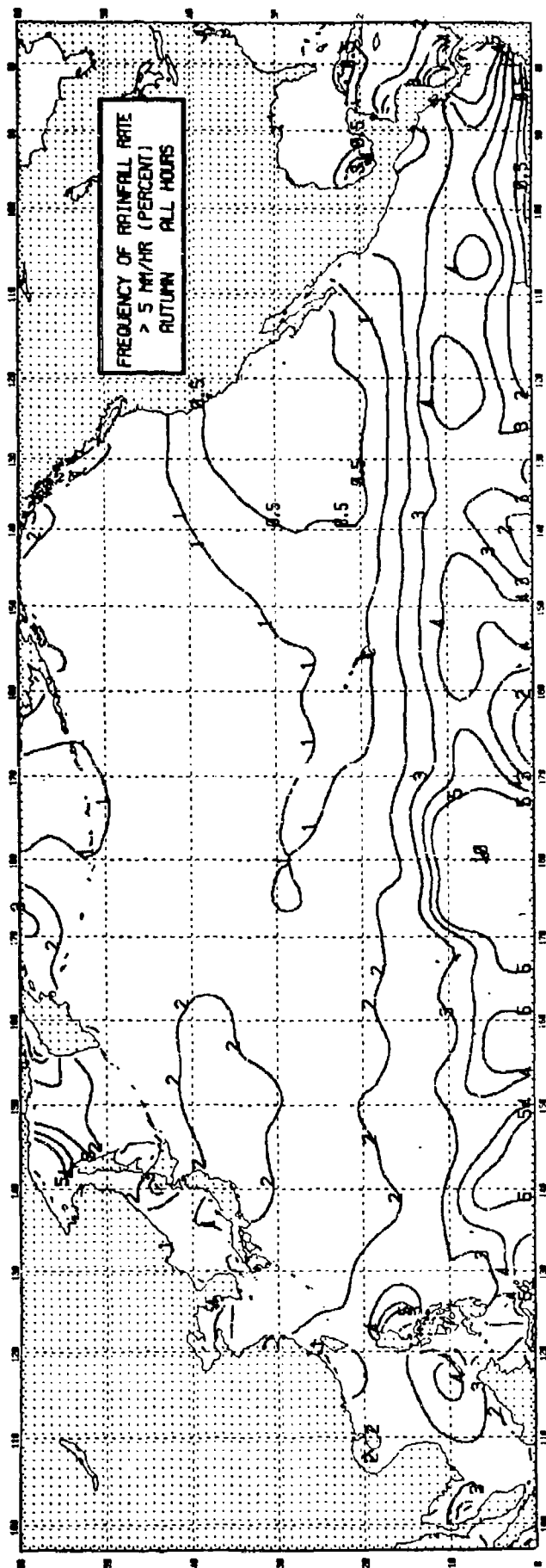


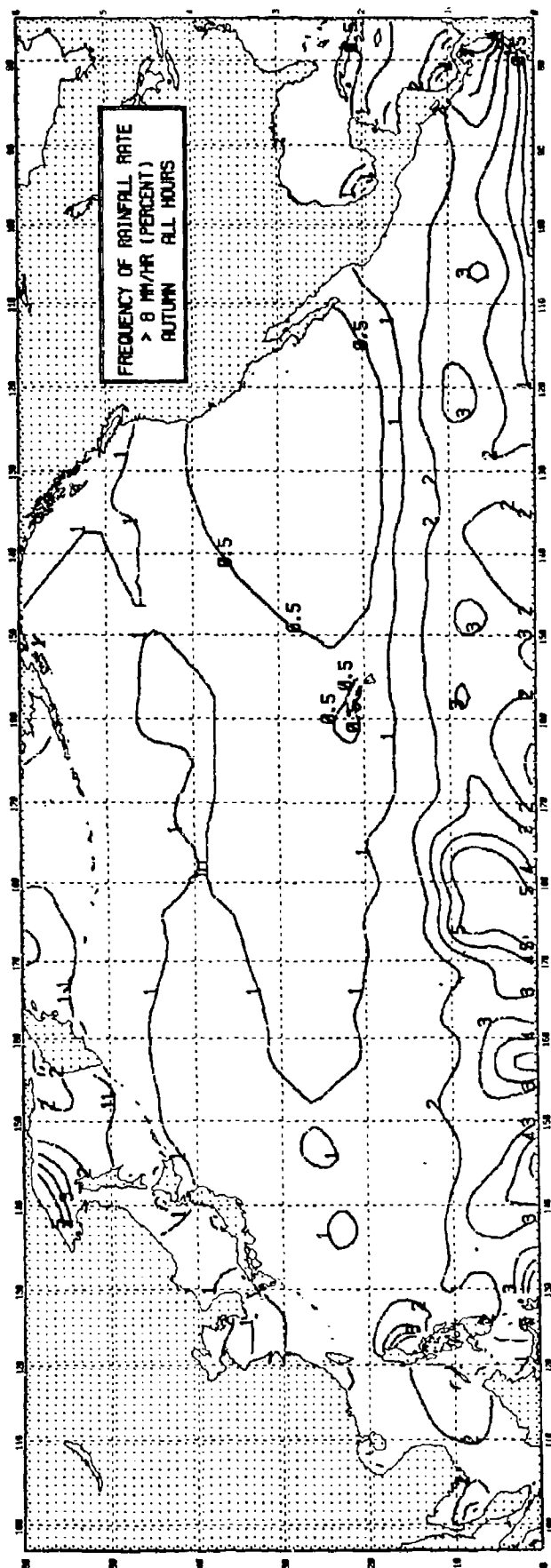


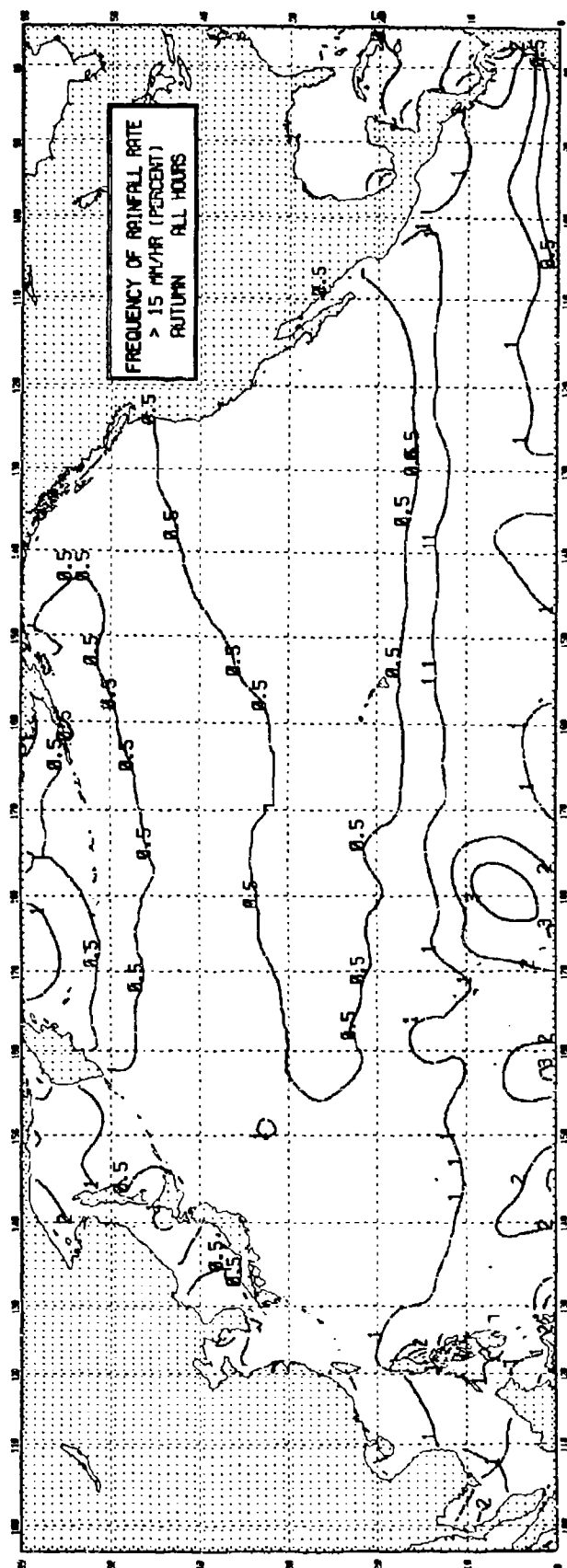


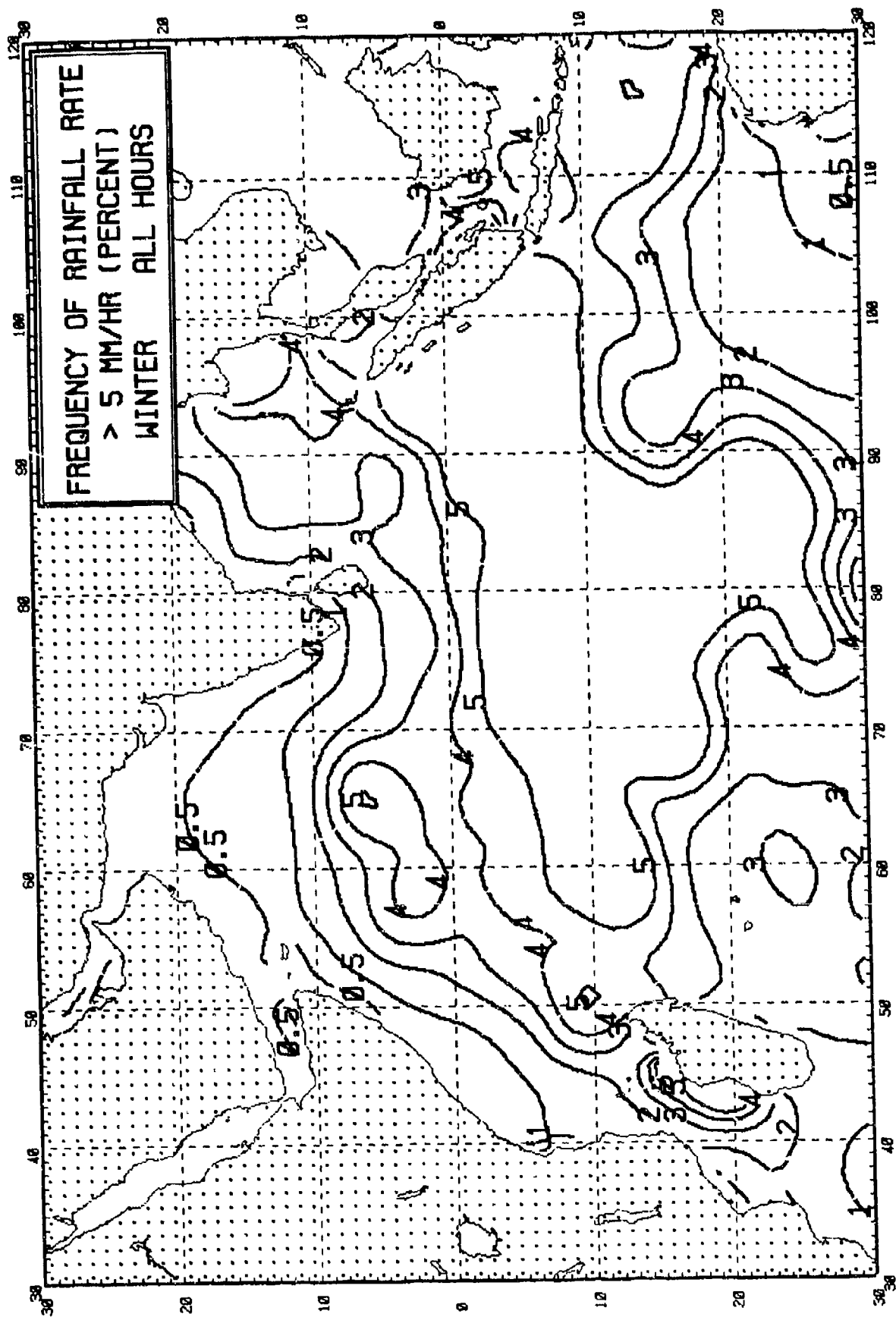


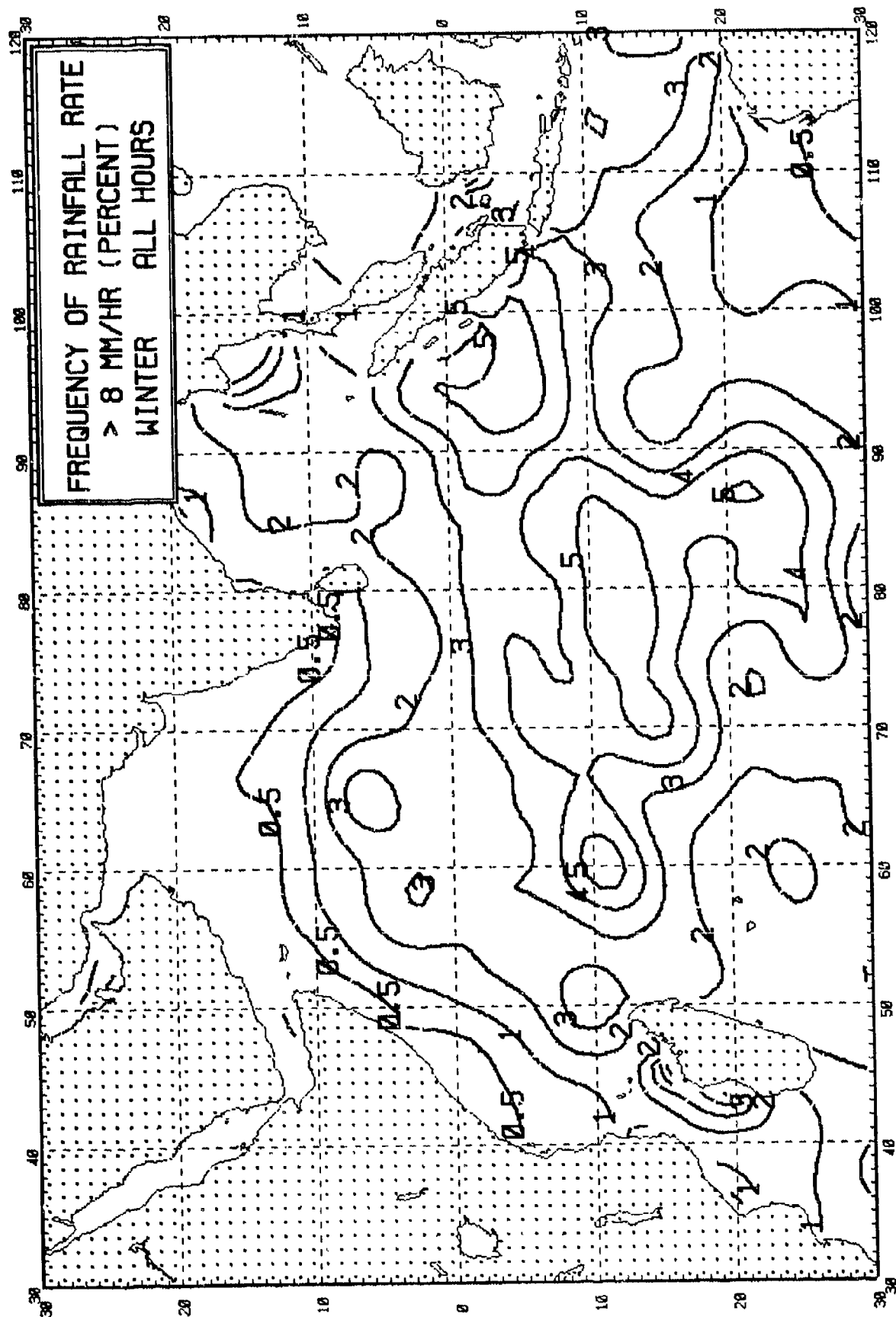


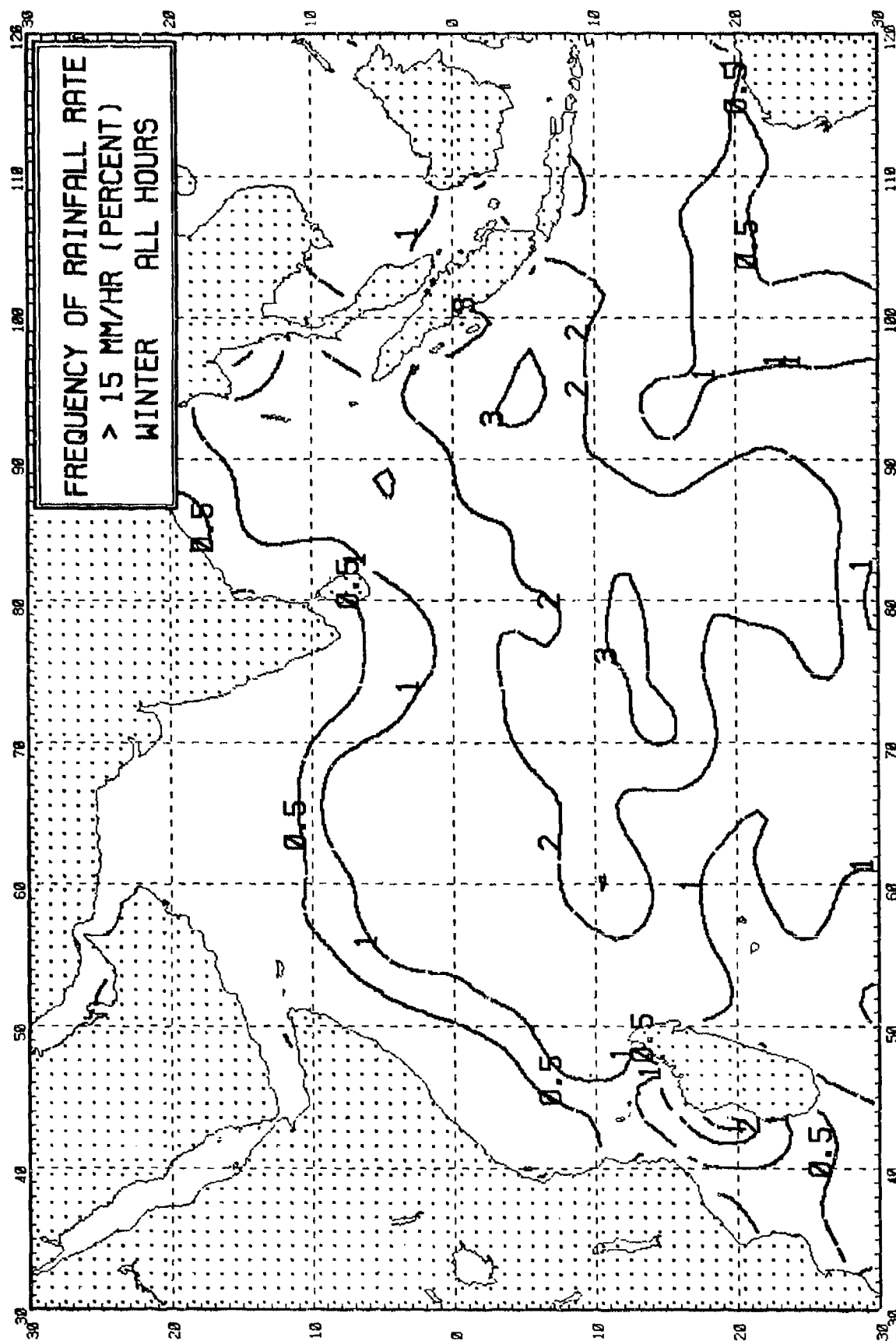


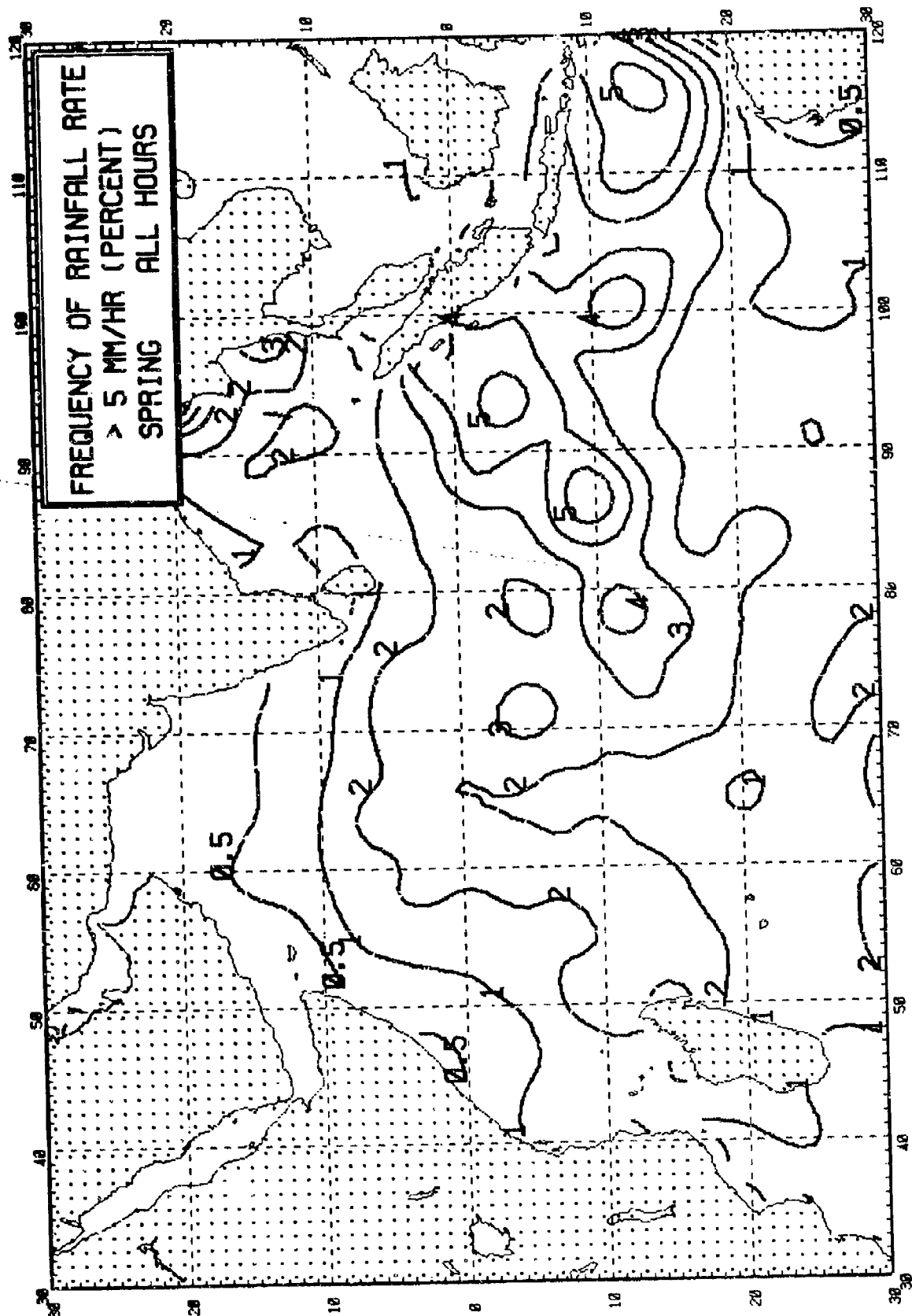


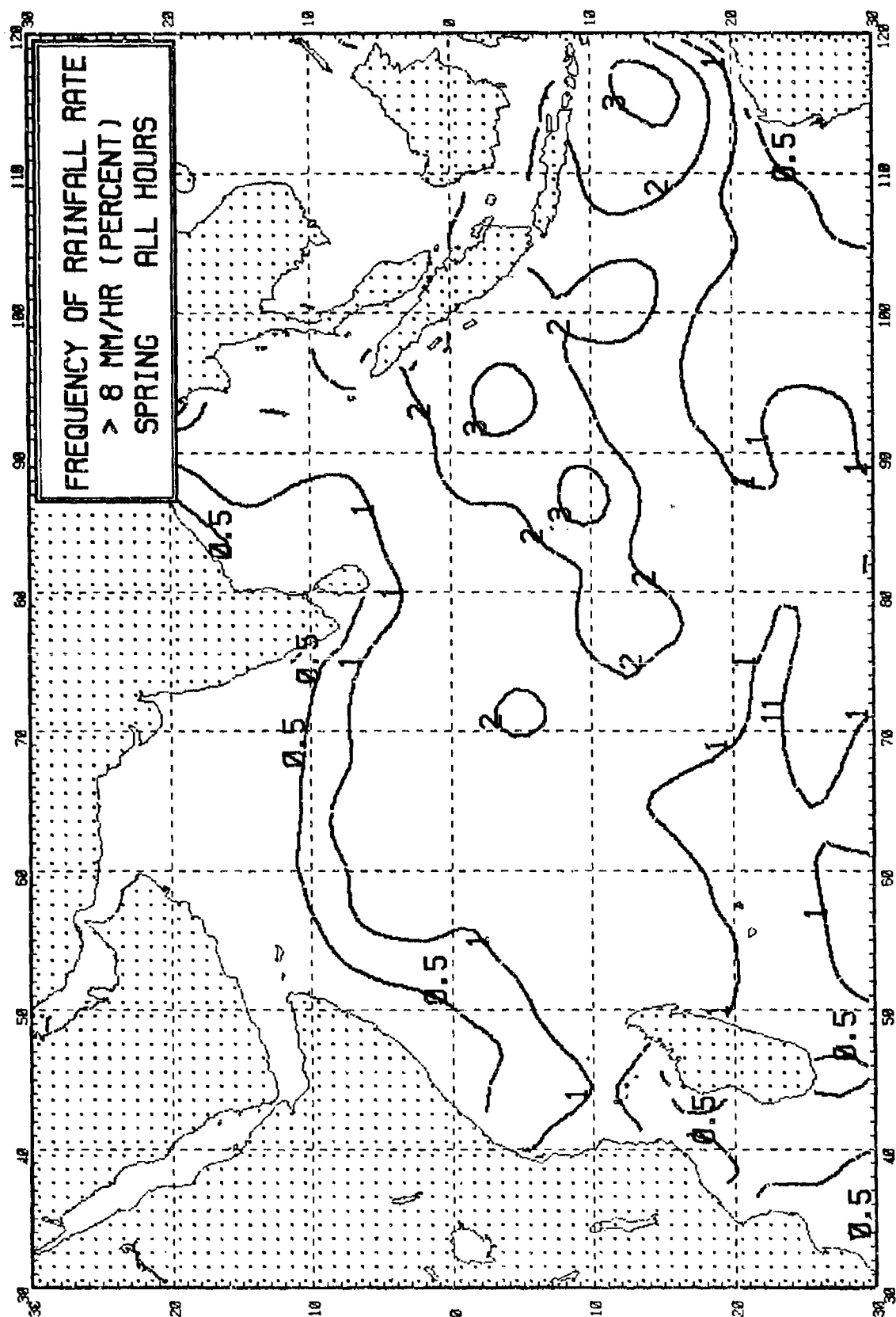


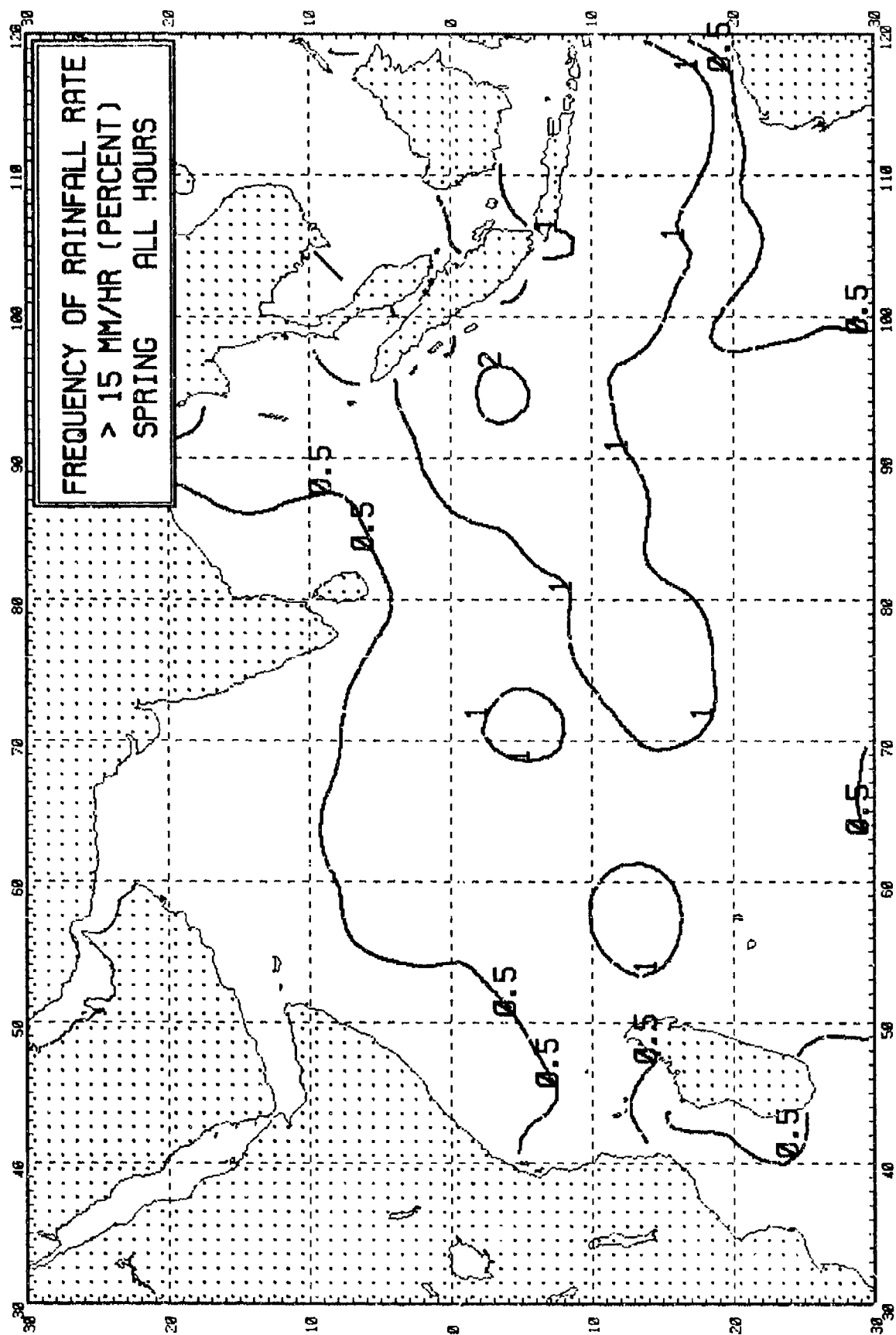


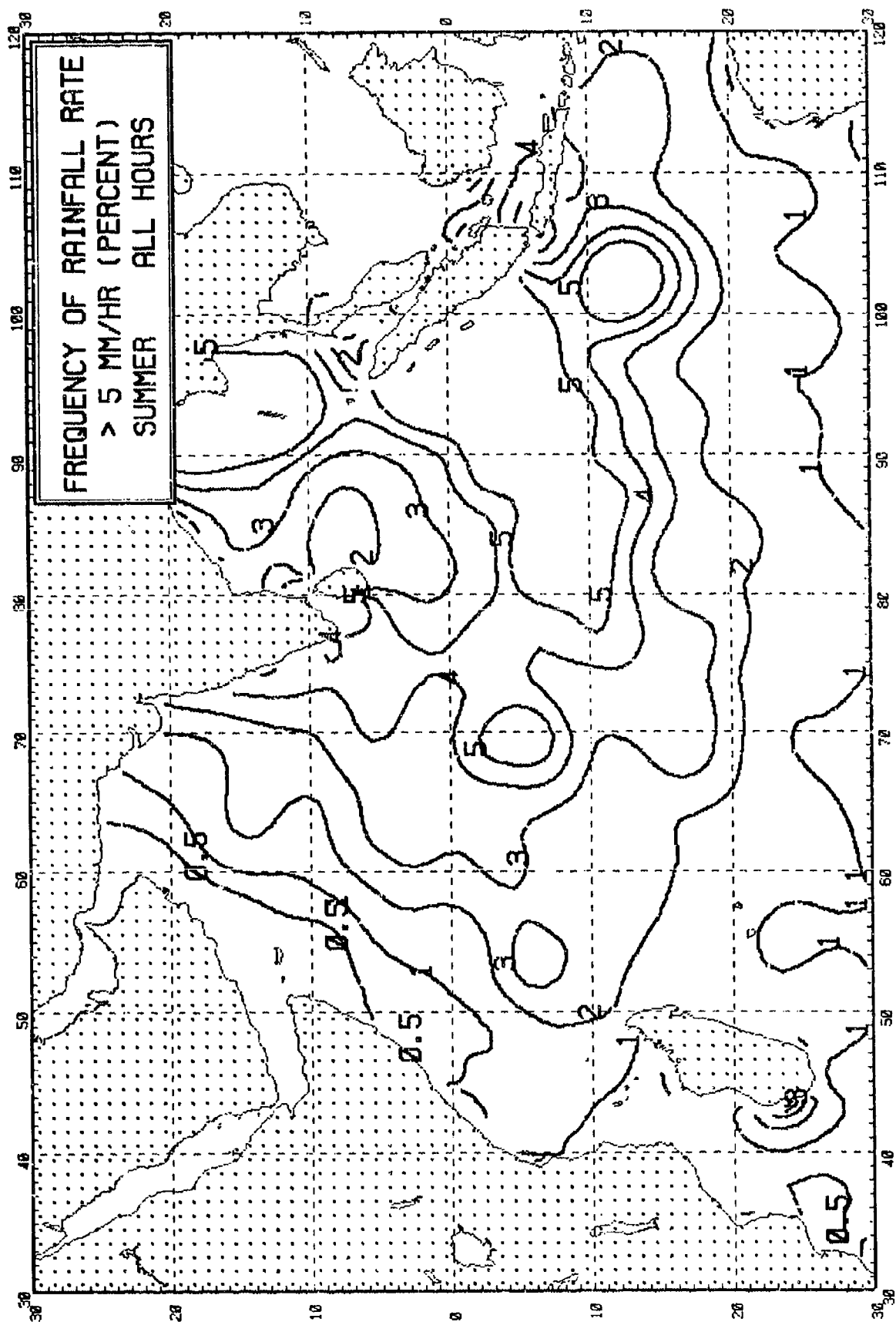


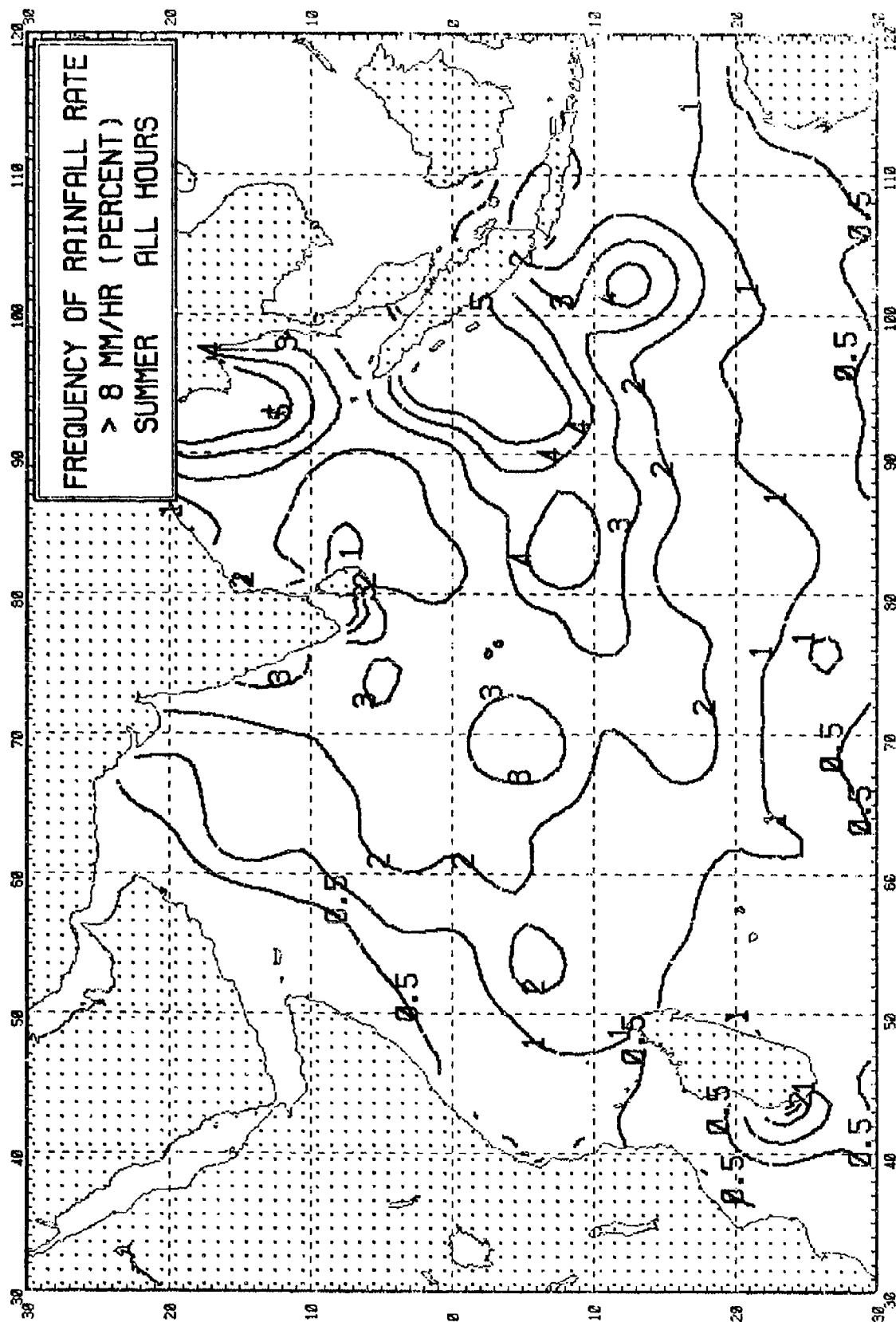


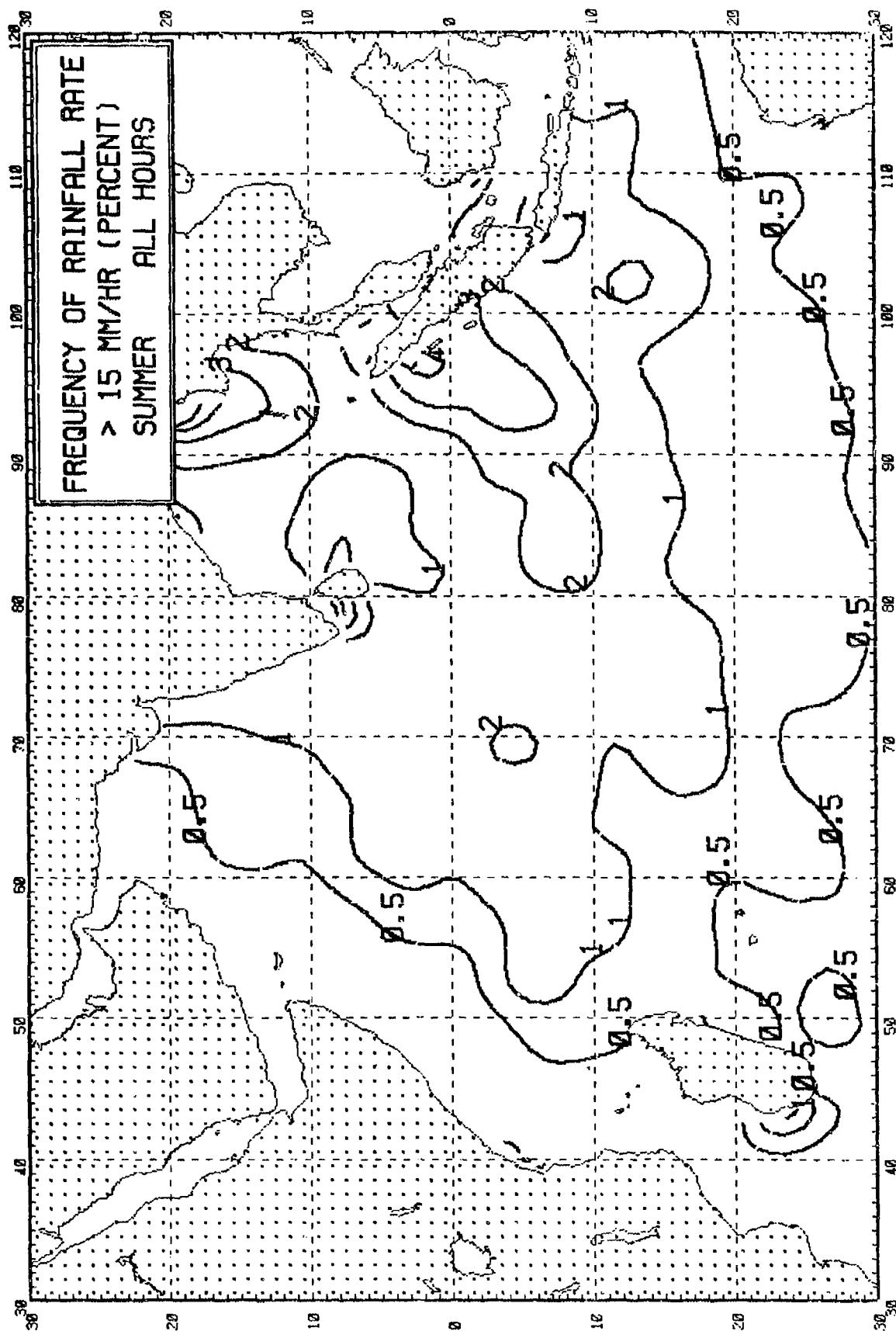


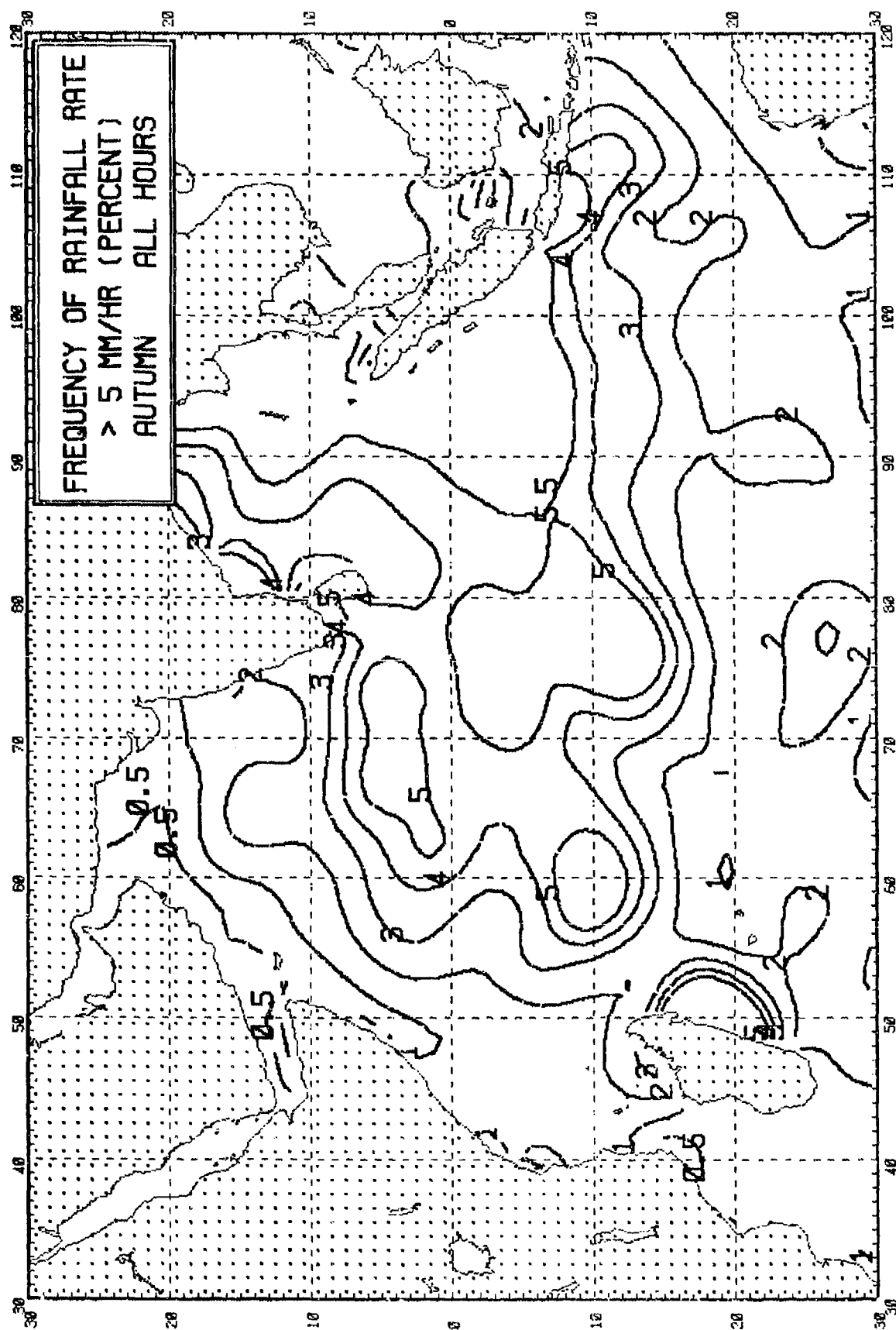


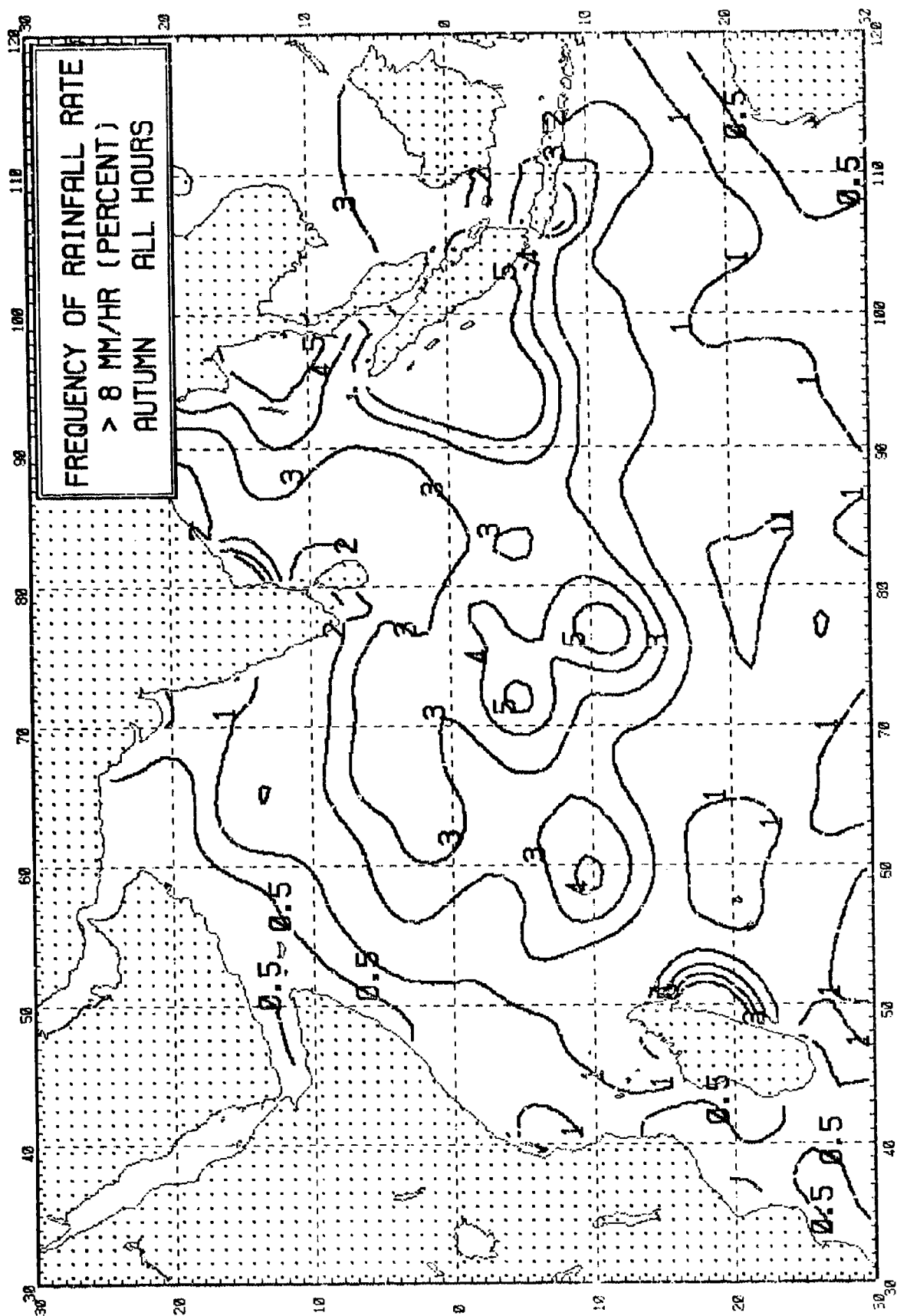


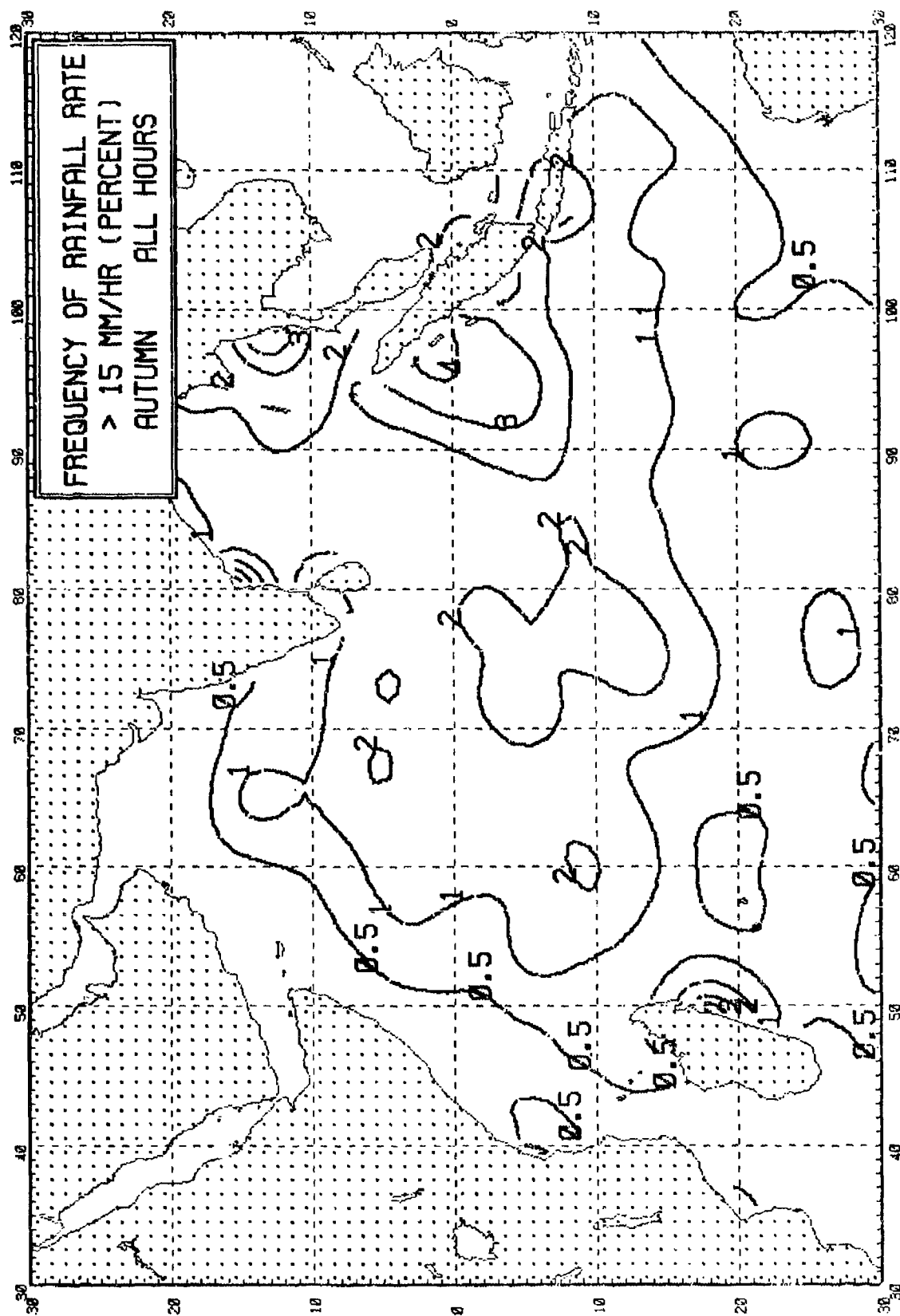


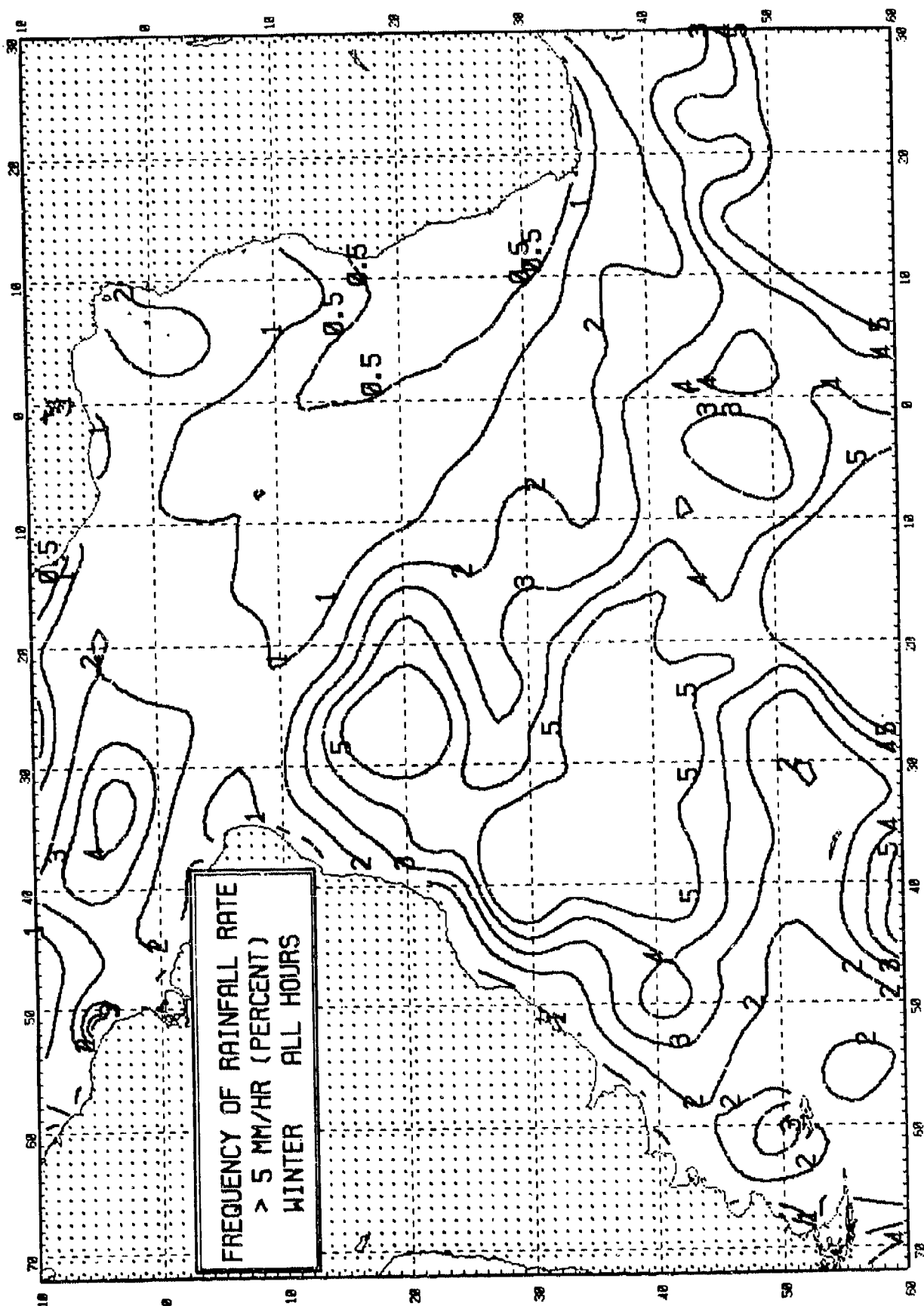




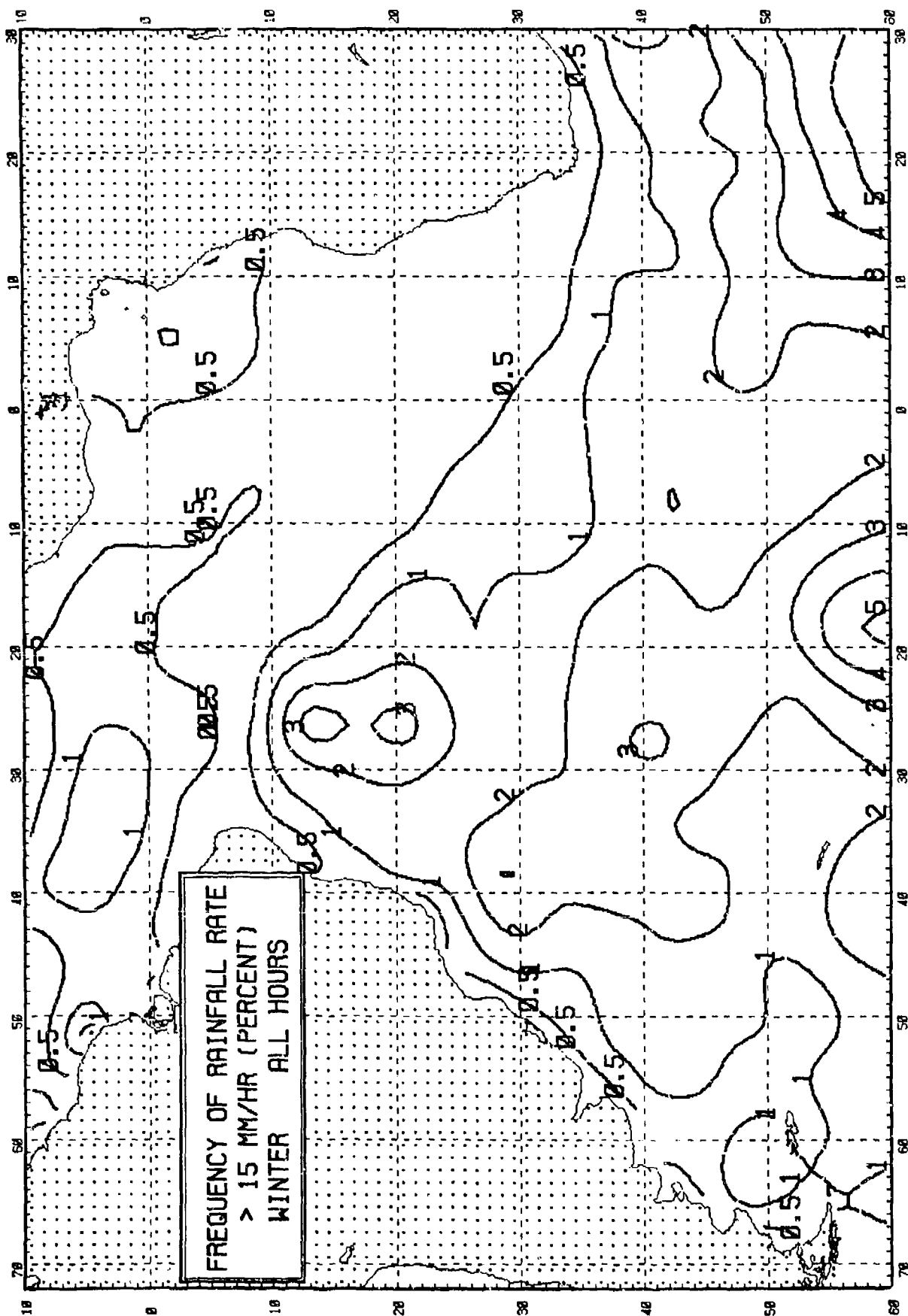


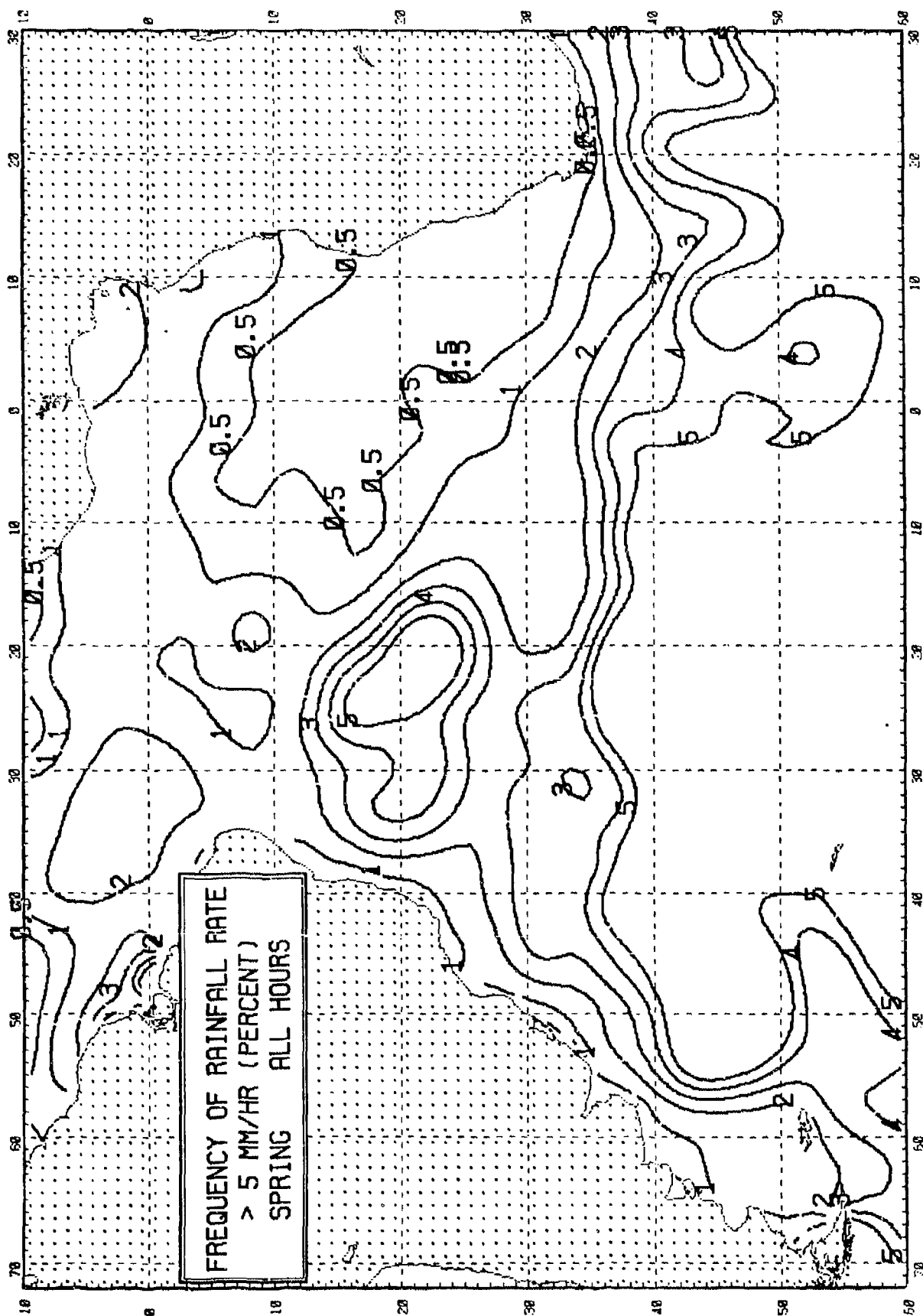


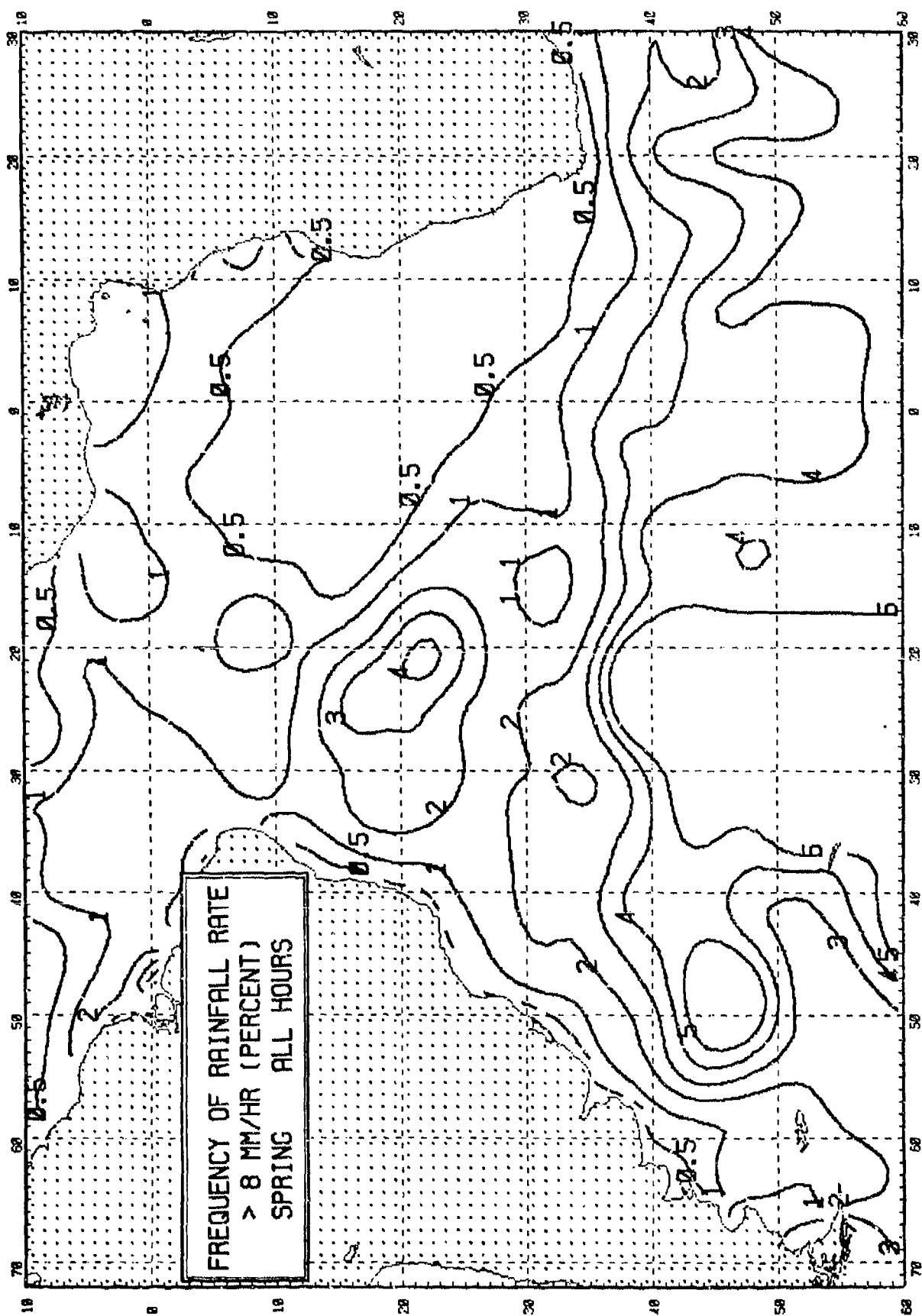


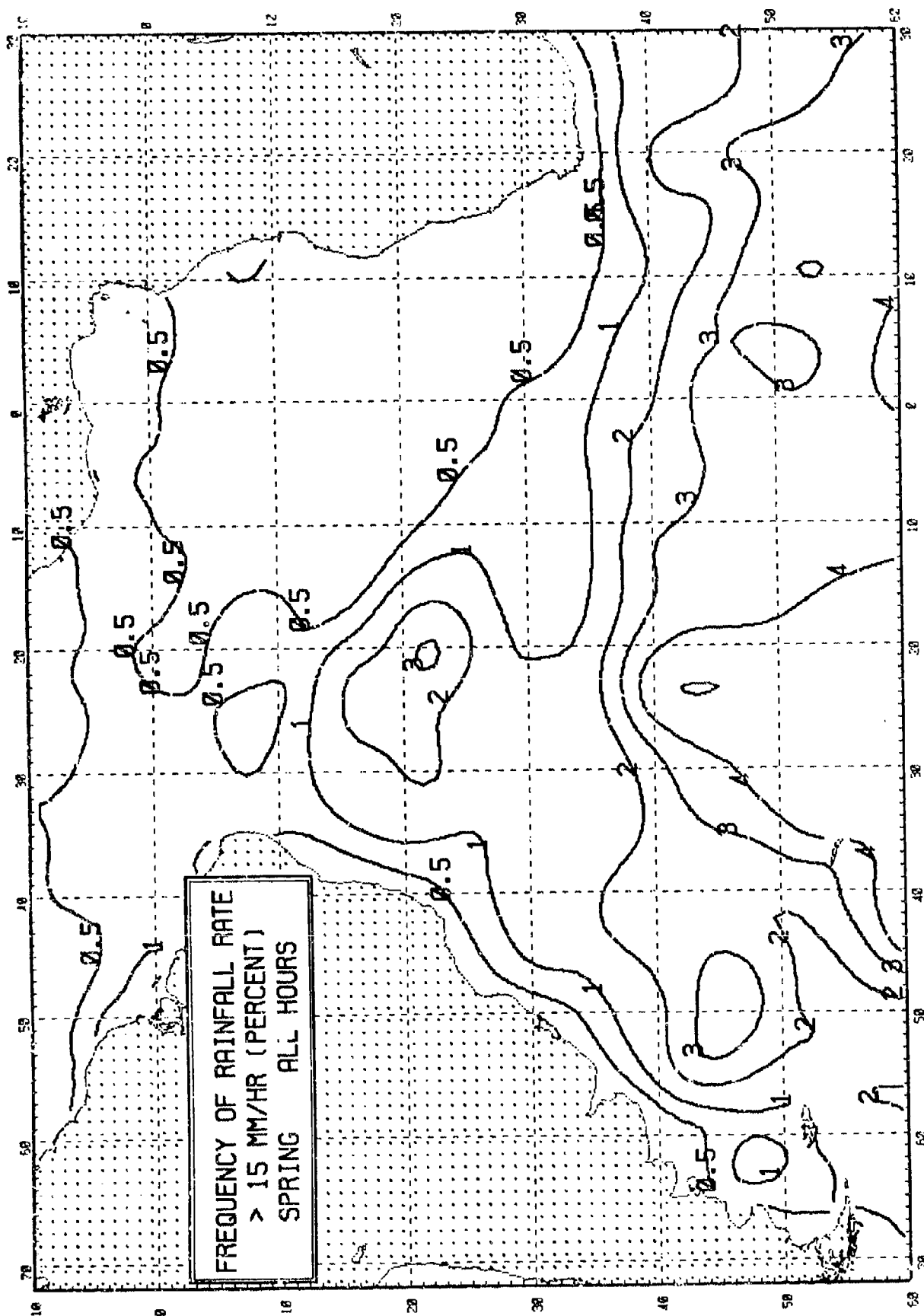


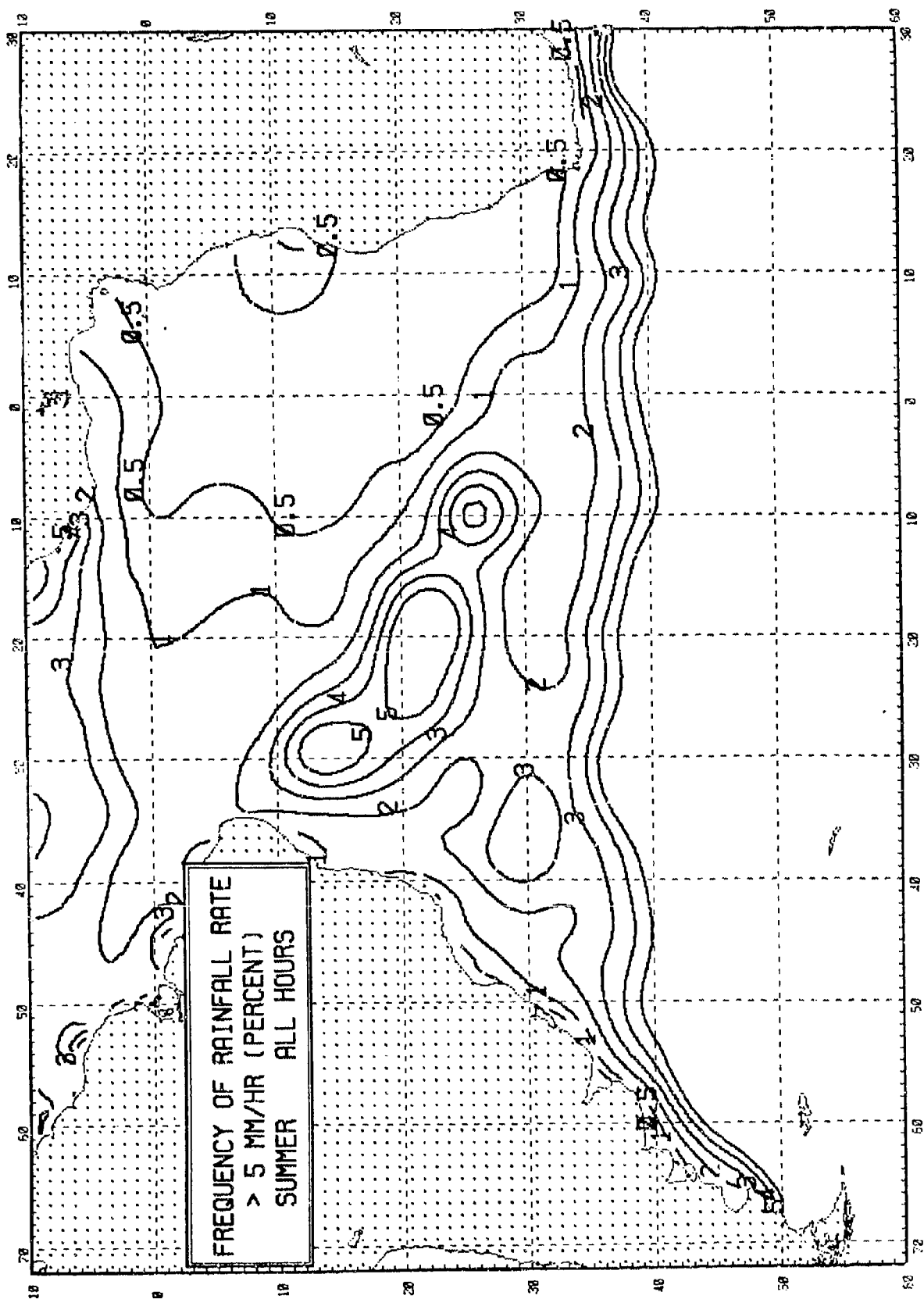


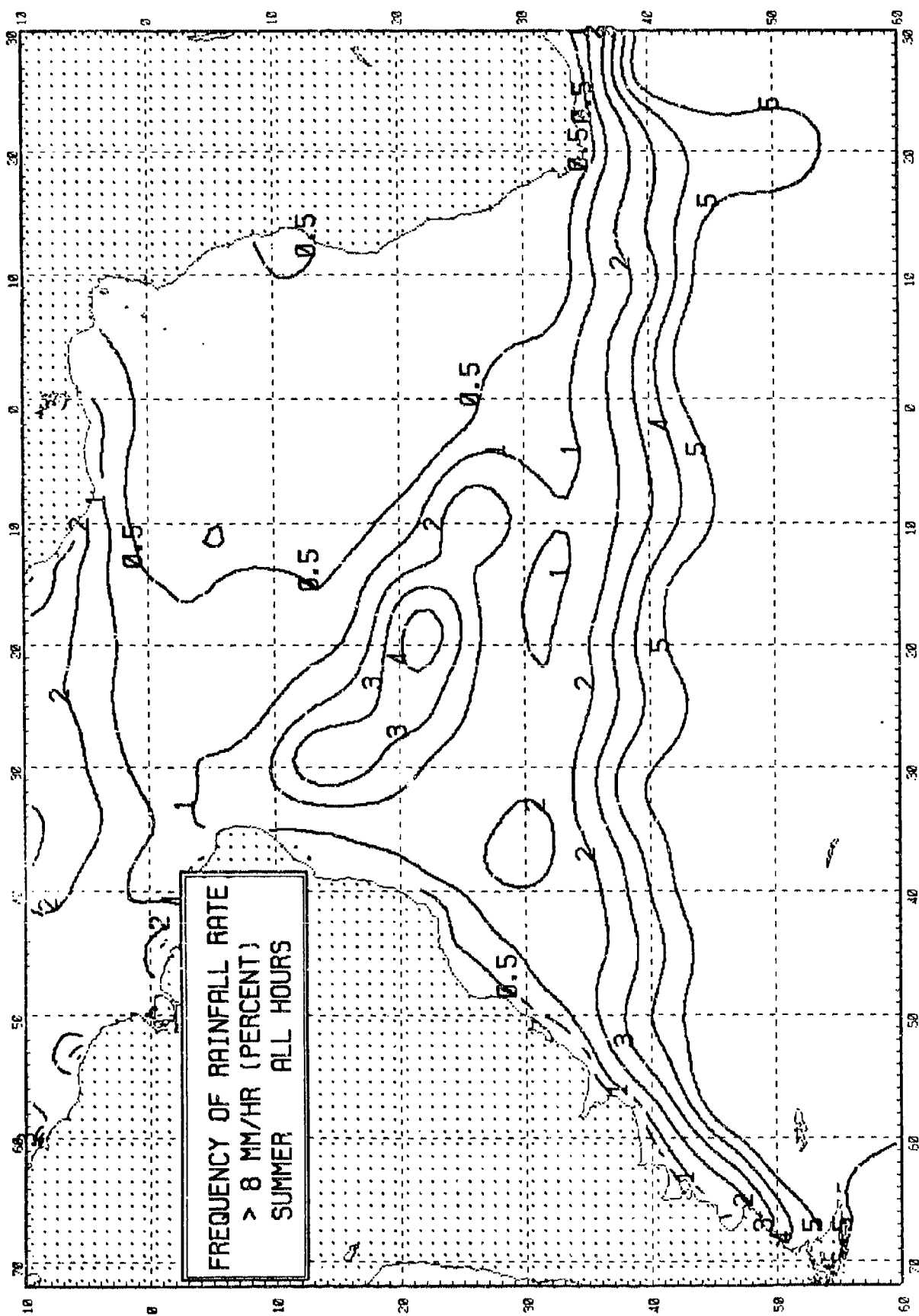


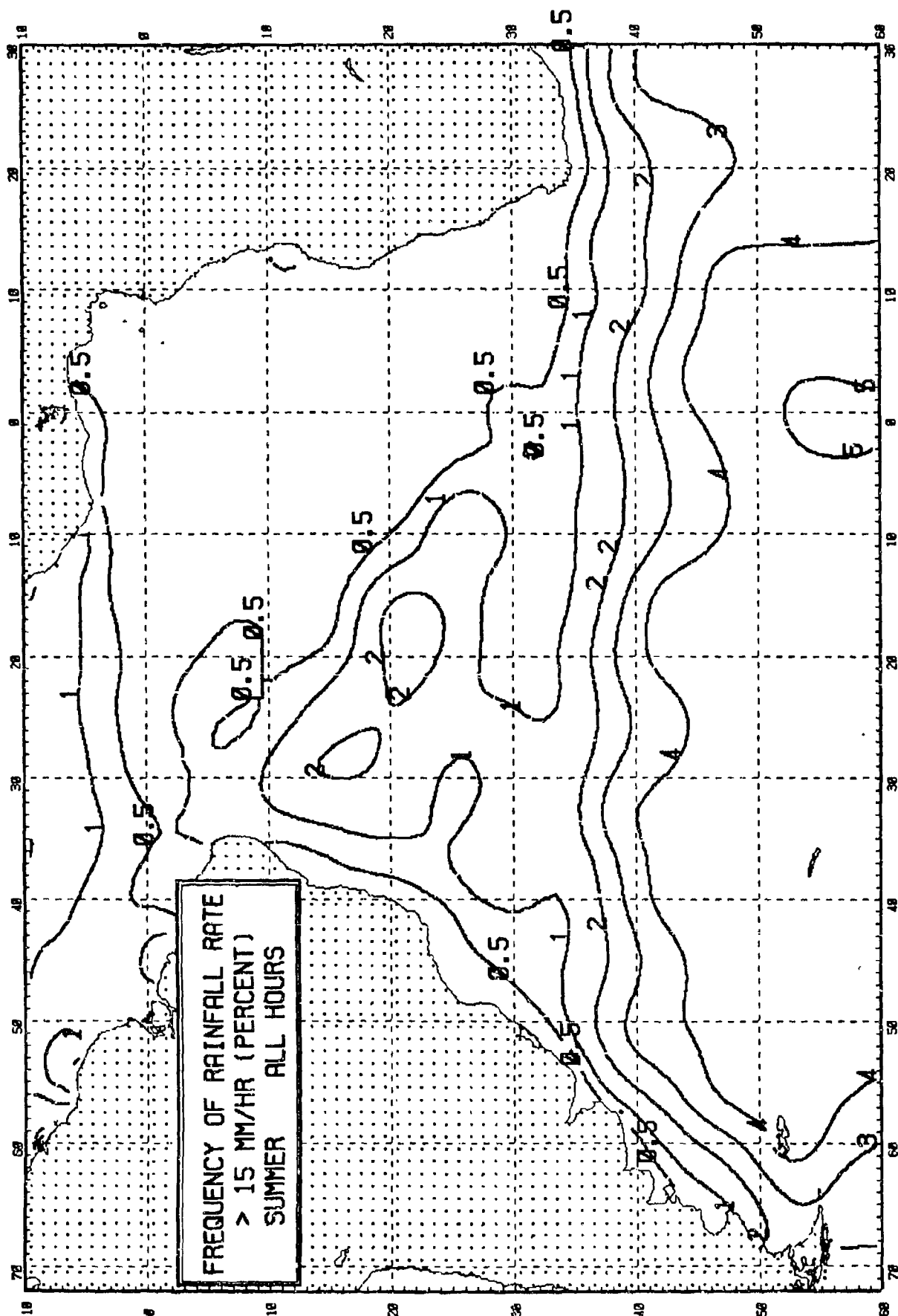


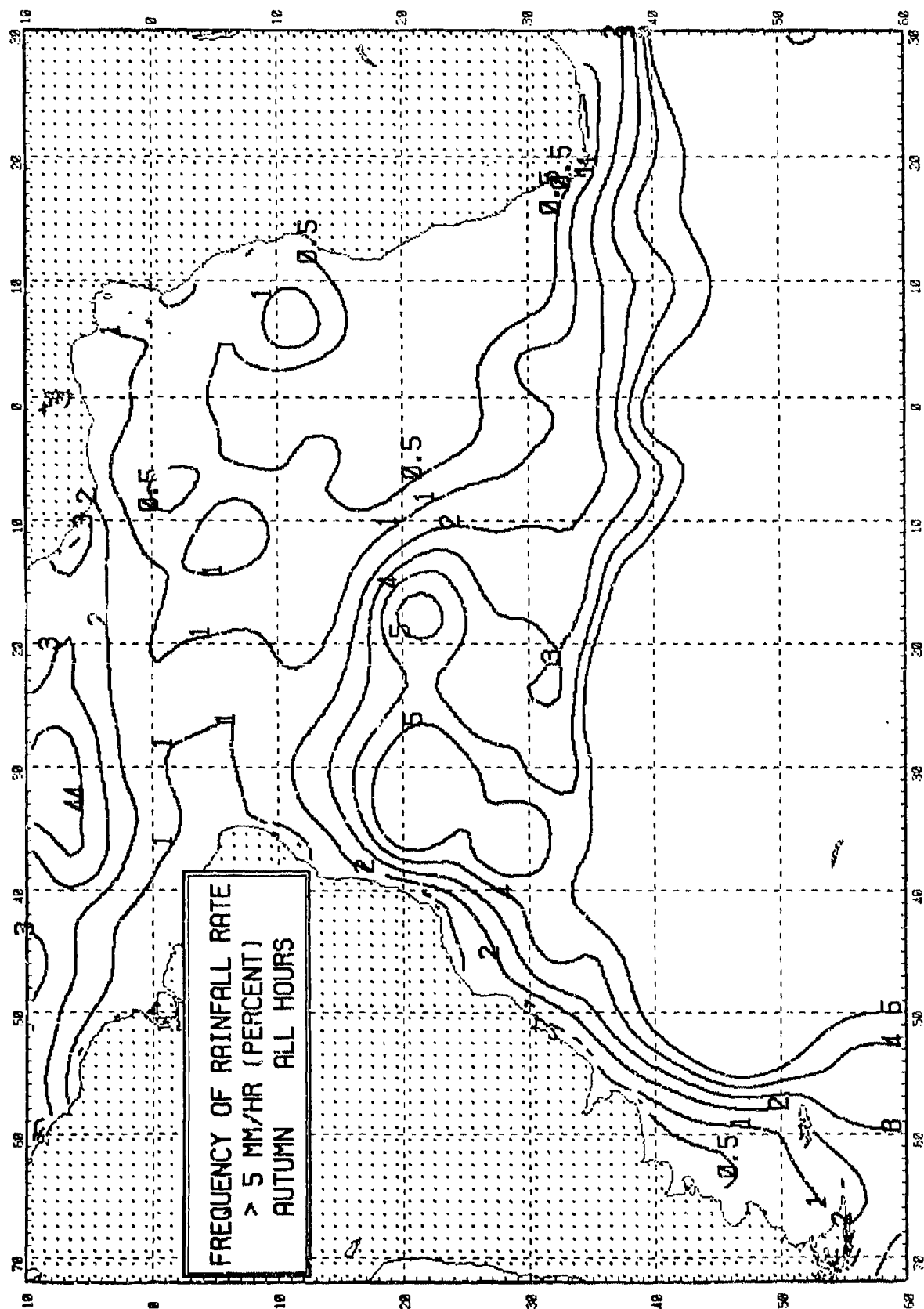


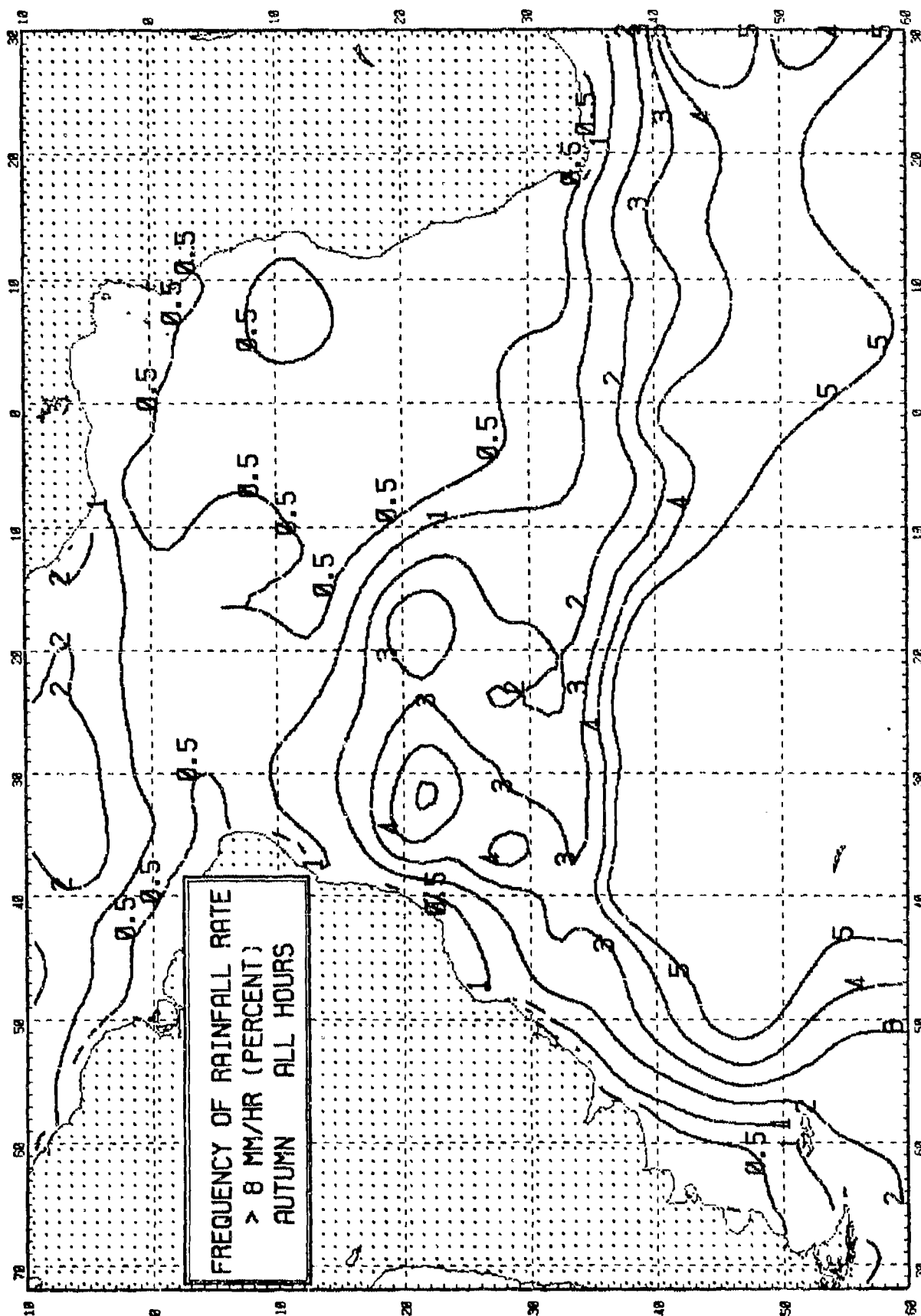


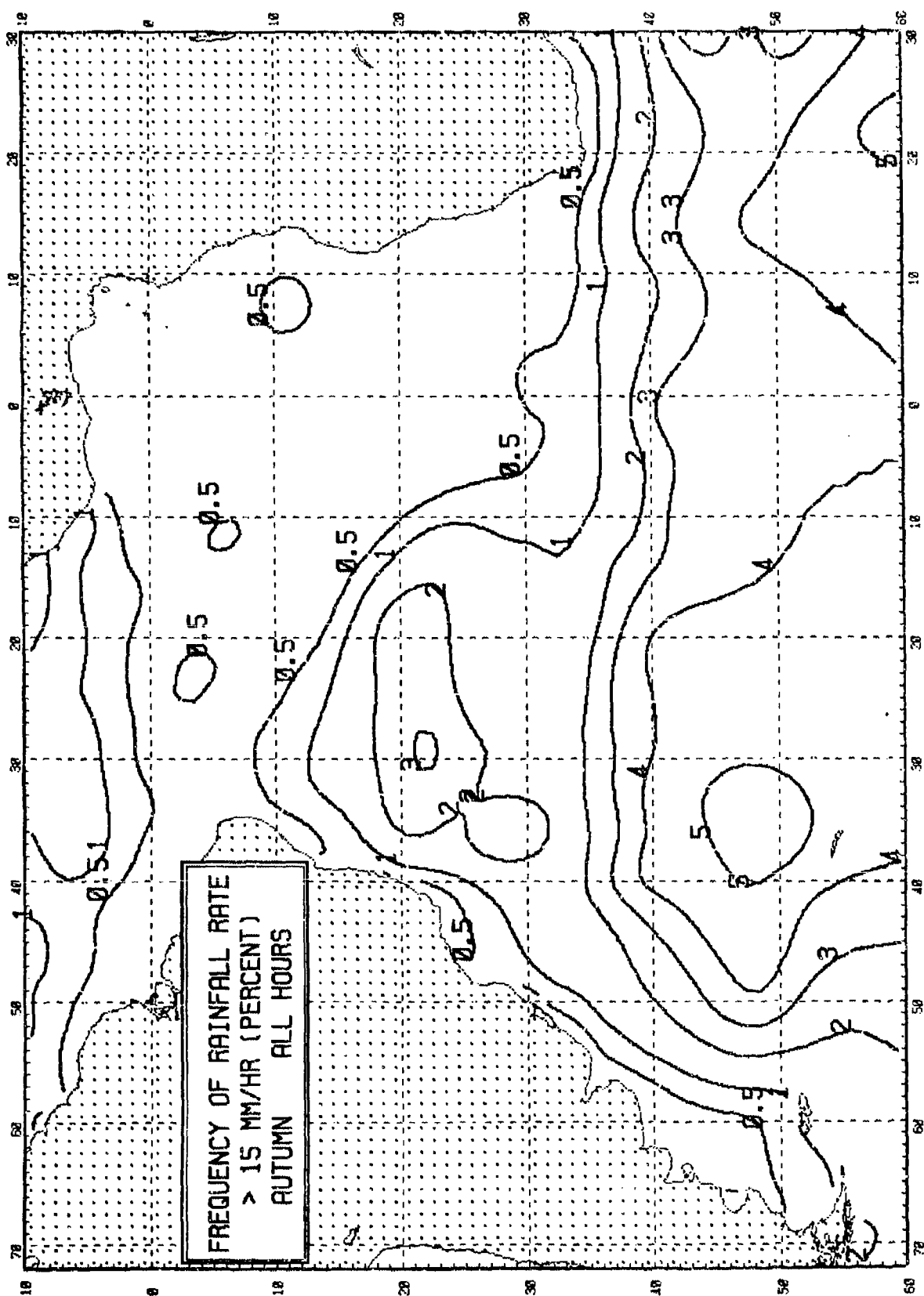


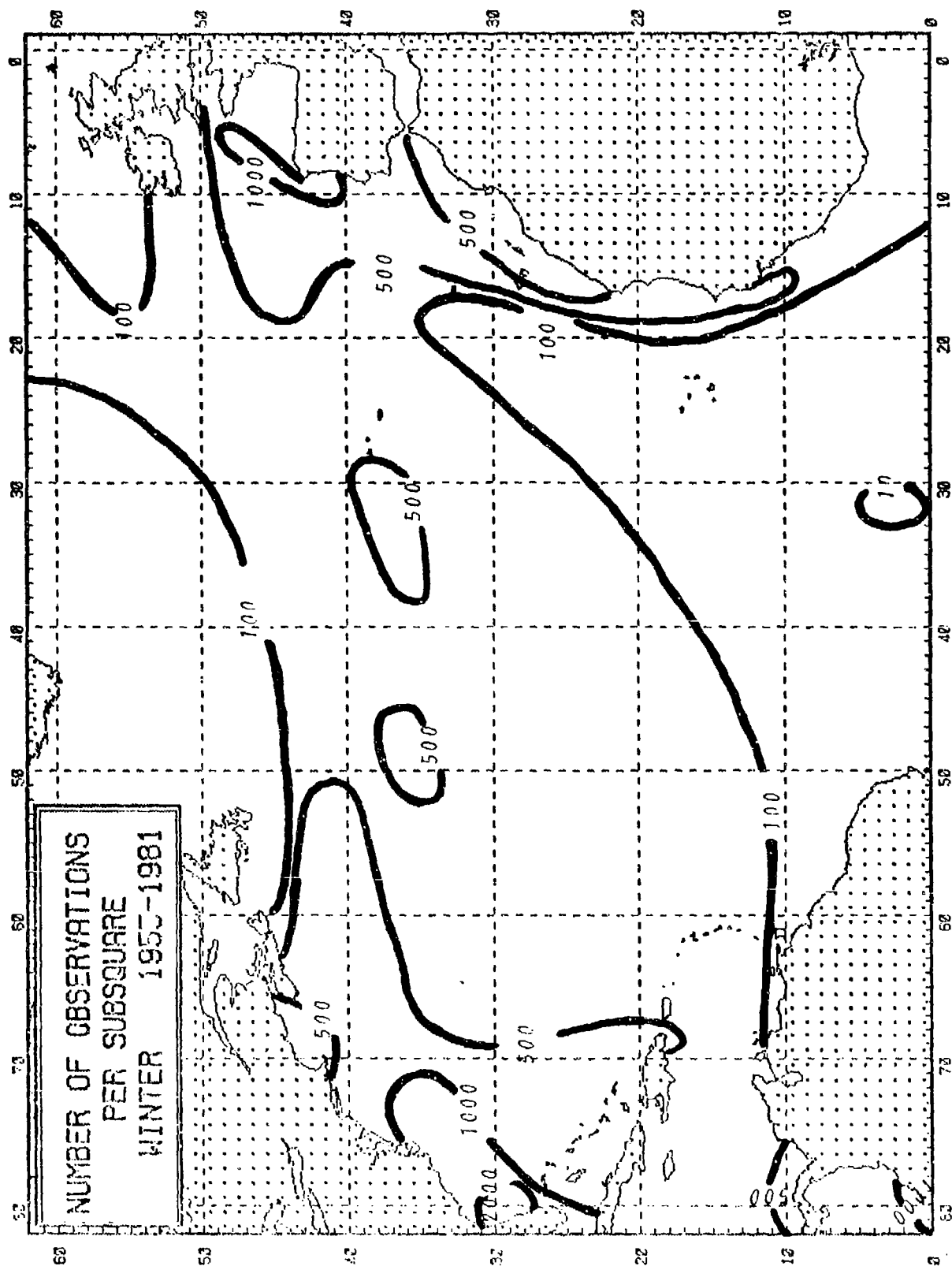


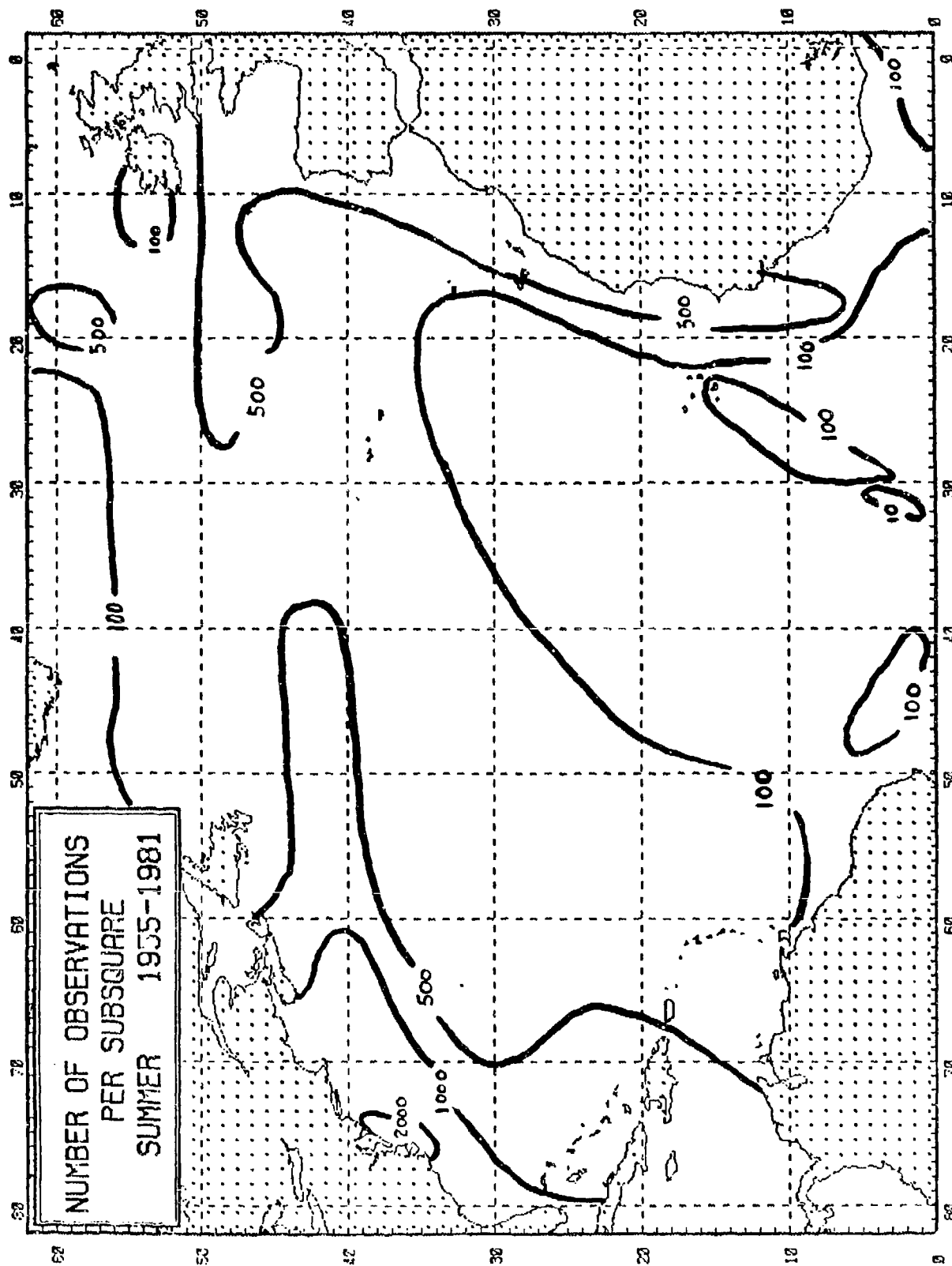


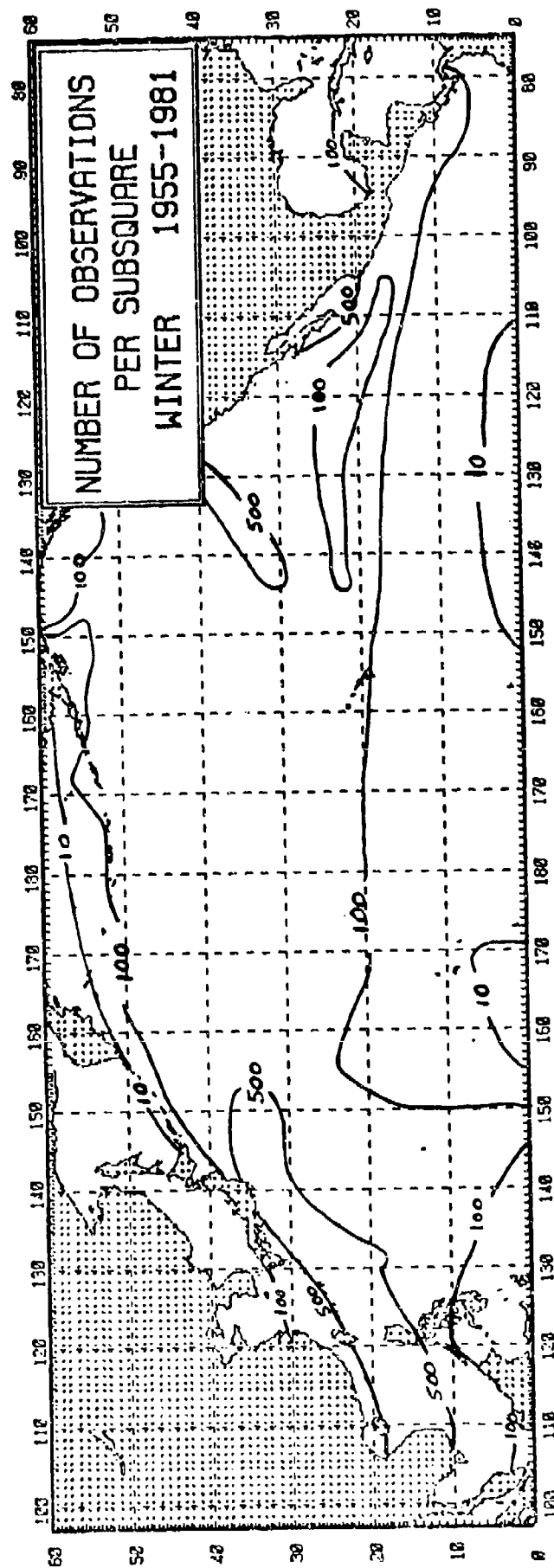


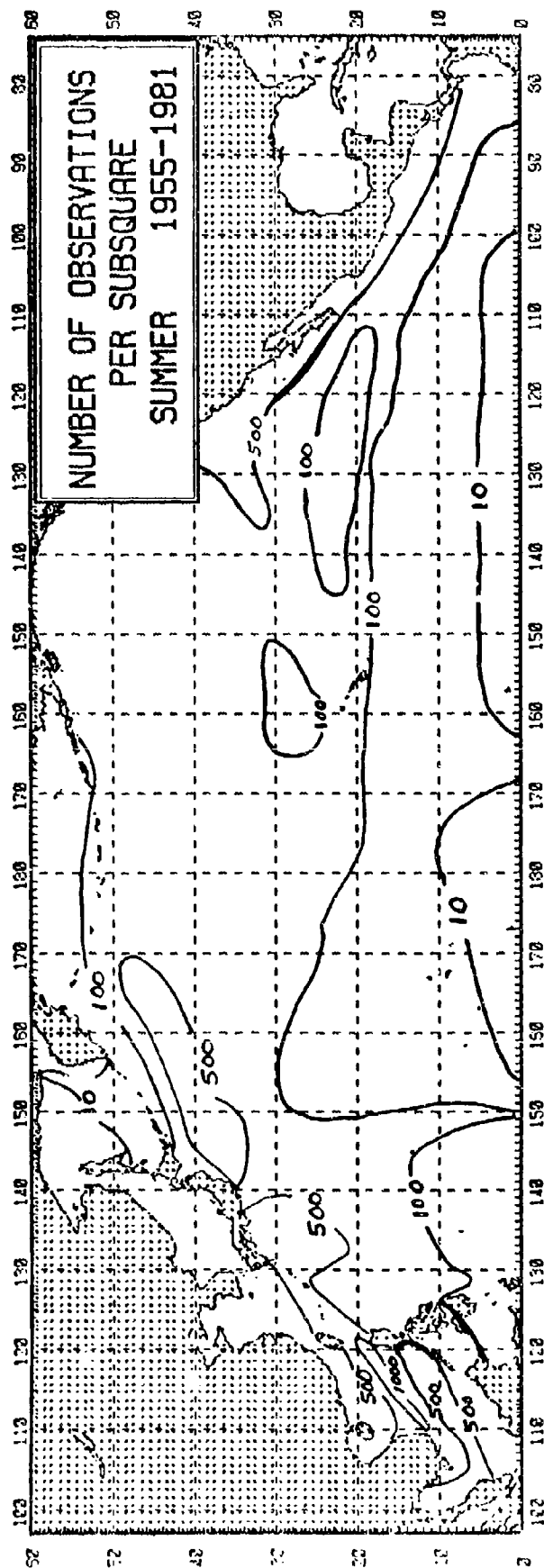


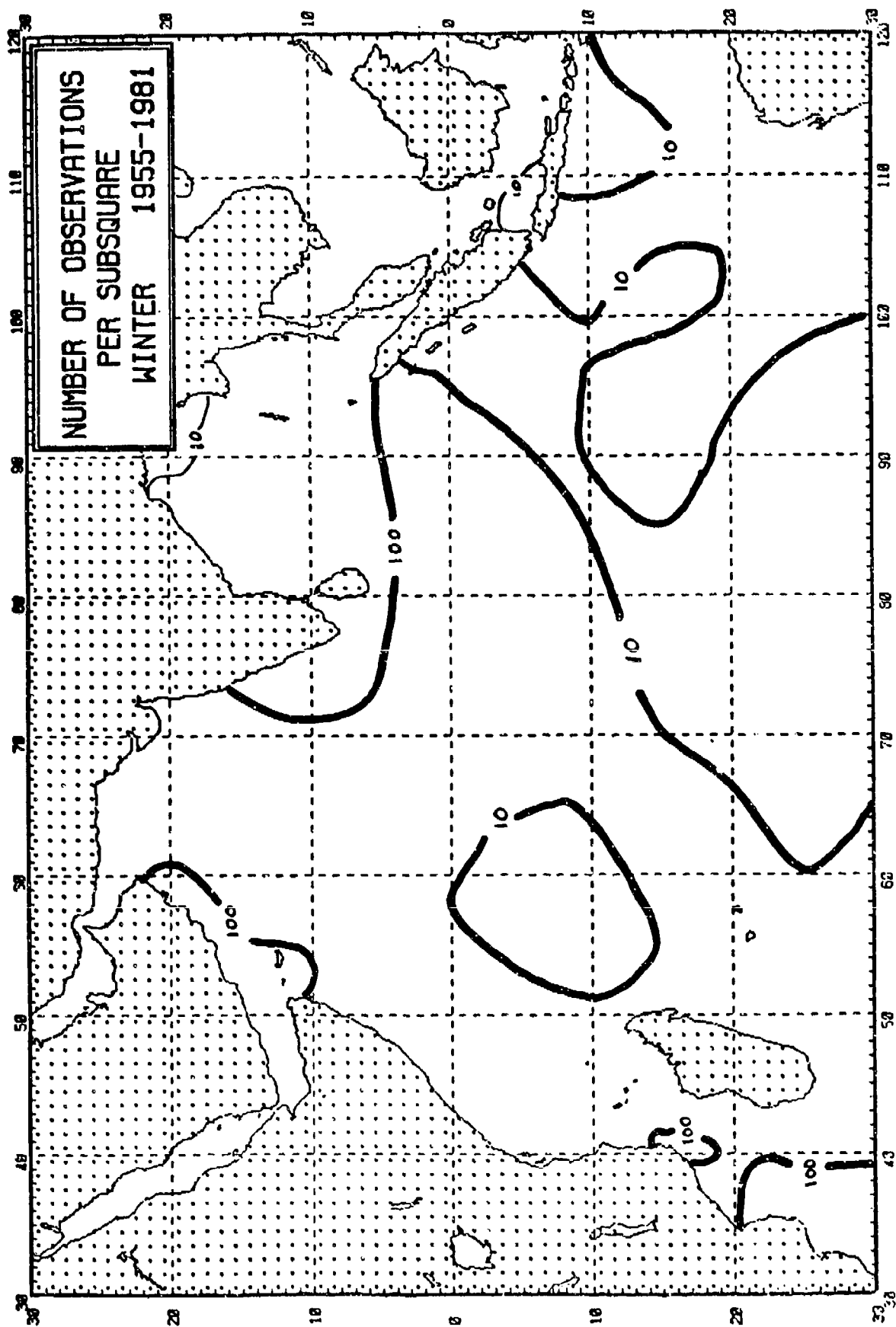


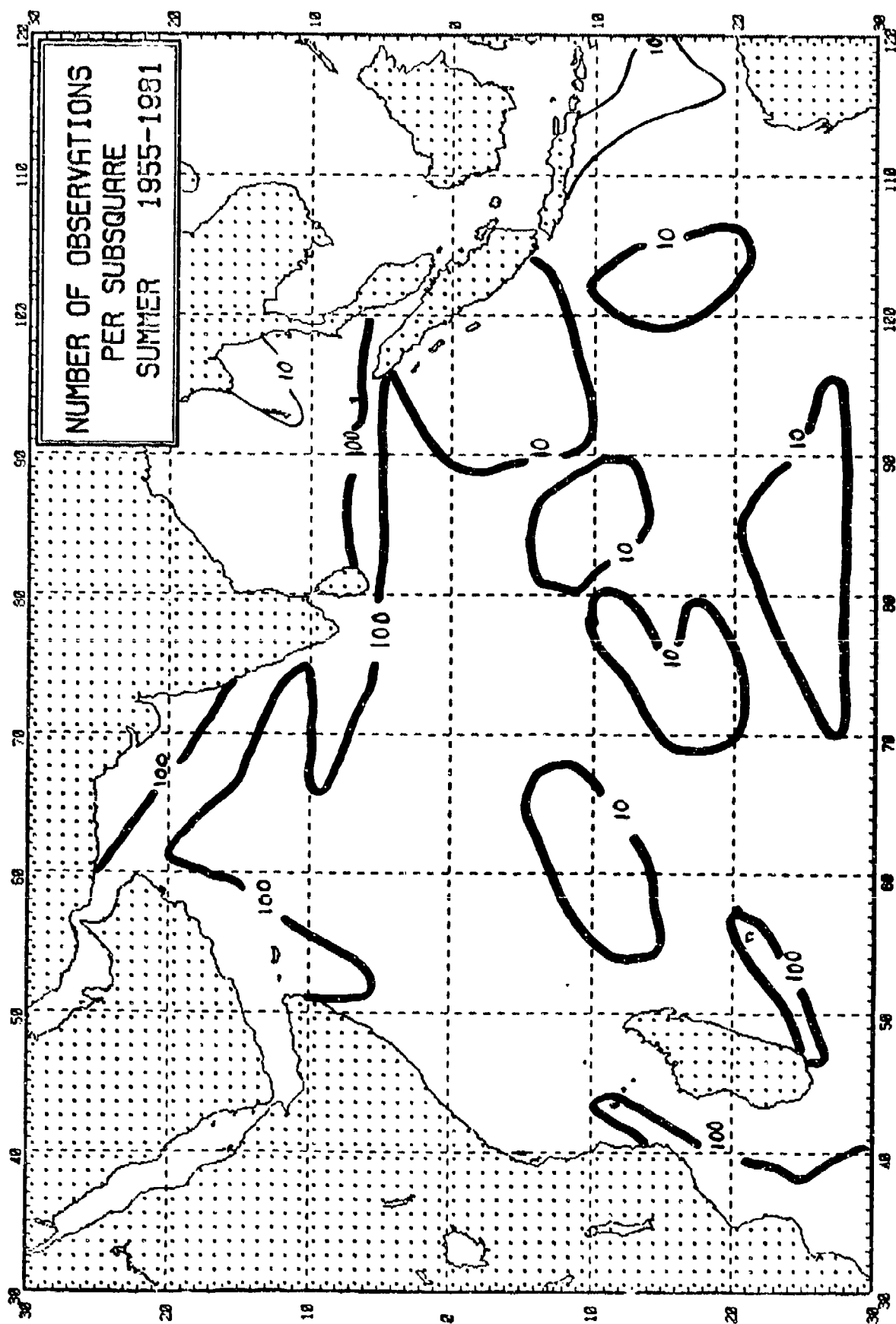


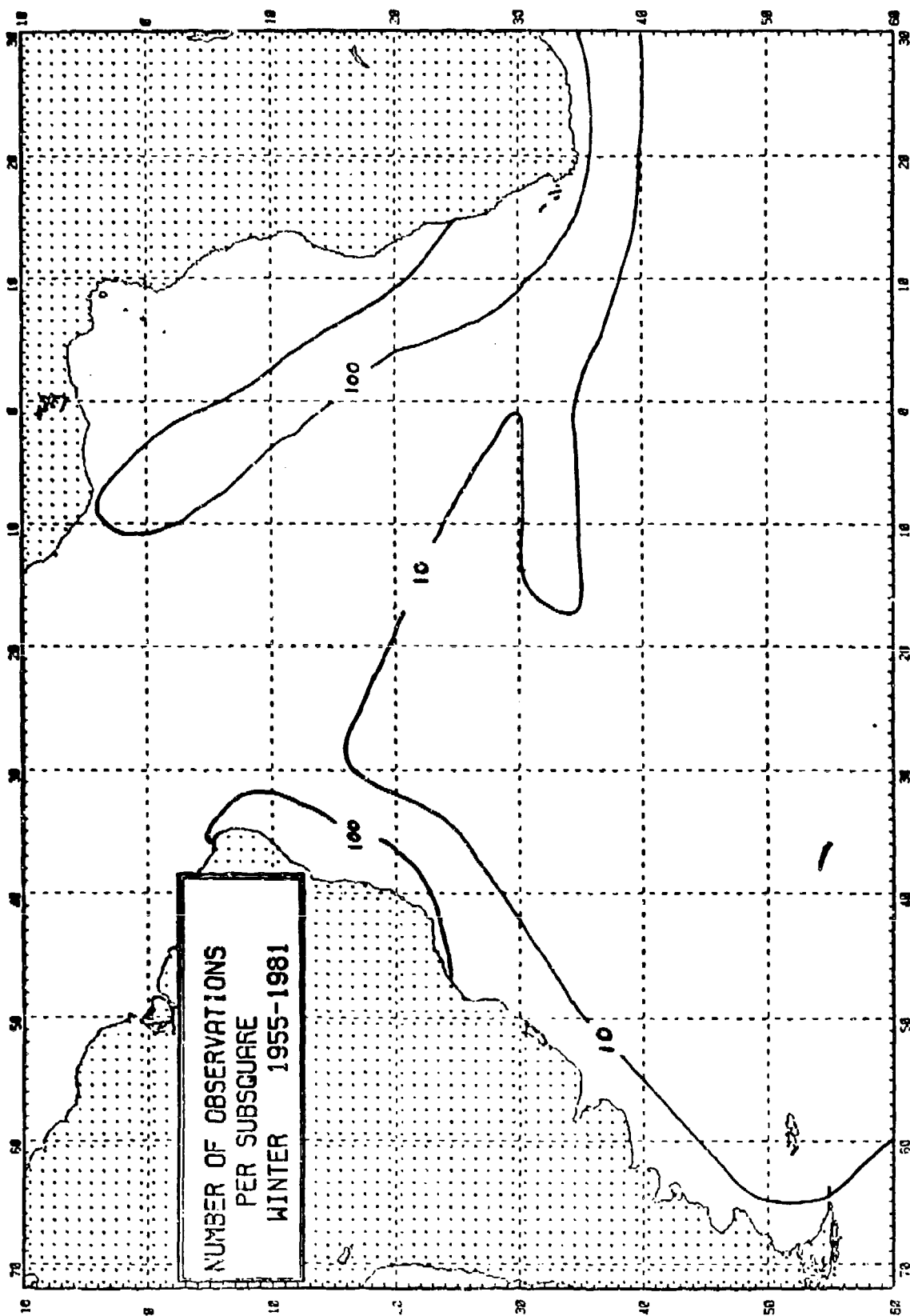


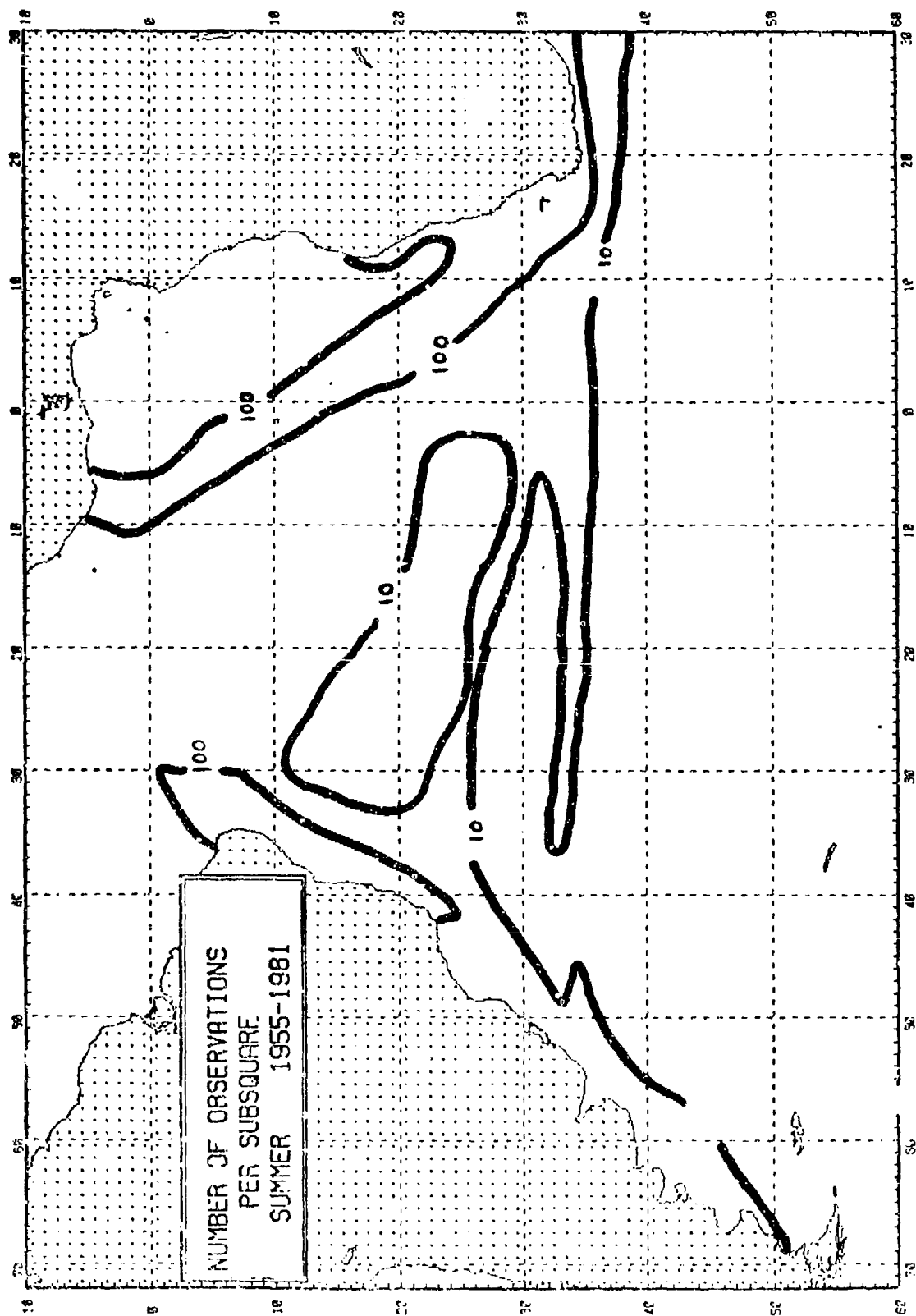












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